The IAA-CSIC 2021 Annual Report is the result of a collective process of the people who make up the Instituto de Astrofísica de Andalucía. We would like to thank all of them for their dedication and willingness to capture the best possible picture of what we do and what we work for.

1st Edition: October 2022
Editor: IAA-CSIC
Coordinators: José Francisco Gómez & Isabel Márquez
Design: Tarma, estudio gráfico
Cover images: HST and MEGARA/GTC composed image of the Planetary Nebula NGC2392 (Guerrero et al. 2021)

Printing: Lozano impresores
Legal dep.: Gr-1832-2021

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The year 2021 offered an excellent opportunity to make a review of the scientific and technical life of the IAA: on the one hand, we were facing the final year of the "Severo Ochoa – IAA" program (July 2018 – June 2022). The Severo Ochoa Excellence award has had a transformative impact on the IAA in terms of attracting international talent, rejuvenating our staff, increasing our output, implementing a novel training program, reinforcing work on strategic infrastructure, international visibility and scientific outreach. At the end of 2020, the mid-term report was presented obtaining the highest grade. On the other hand, it was the time to define the new strategic plan for our center, within the framework of the "CSIC Action Plan 2022-2025". We had a good starting point: the IAA has a strong track record, producing a sustained, large number of high impact work. From a technical side, we contribute to almost every major recent space Solar System mission and participate in state-of-the-art instruments for ground-based telescopes. Moreover, the IAA is recognized as an international center of reference for radio astronomy, with critical involvement in the Event Horizon Telescope and the commitment to establish an SKA Regional Centre (SRC).

We defined a set of strategic lines on which we will focus our activity in the coming years: leading multidisciplinary studies of exoplanetary systems and their architecture, deepening the study of the star-planet interaction and exoplanet atmospheres, using our background in radiative transfer models in non-ETL conditions; continuing our leadership in the EHT and in the future ngEHT to obtain the first movies of the supermassive black hole at the center of our Galaxy; exploiting our unique capabilities for the study of star formation and nuclear activity over the full range of relevant physical scales and distances; obtaining an unprecedented 3D map of the universe, via the J-PAS survey, relevant for the study of galaxy formation and evolution; becoming one of the nodes of the SRCS in Europe addressing the most ambitious challenge in radio frequency astronomical observations; leading at IP/co-IP level frontier instrumental projects for space exploration as Comet Interceptor, EnVision, Vigi/Lagrange and SUNRISE 3; strengthening our scientific and technical leaderships in the ESFRI projects in Astronomy; leading the development of the new integral field spectrograph for the CAHA 3.5m
Weiß et al.; NASA/CXC/CfA/R. Kraft et al.; EHT/M. Janßen et al.

SKA precursors results from (MeerKAT, ASKAP, LO). New at the heart of the nearby galaxy Centaurus A. Additionally, the EHT pinpointed the central black hole was imaged for the first time. The structure of the EHT, understanding giant magnetar flares. With the tail measuring distinct oscillations in its brightness was studied in de-. A glimpse into the possible future of the Solar System and a Jovian-type planet was discovered, providing the other hand, a system formed by a white dwarf a new tool for the study of exoplanetary systems. On the radio light curve and the orbital period, provided of Proxima Centauri, showing a correlation between field of exoplanets, the study of the radio emission was observed with data from MEGARA/GTC. In the field of exoplanets, the study of the radio emission of Proxima Centauri, showing a correlation between the radio light curve and the orbital period, provided a new tool for the study of exoplanetary systems. On the other hand, a system formed by a white dwarf and a Jovian-type planet was discovered, providing a glimpse into the possible future of the Solar System. An eruption of a magnetar was studied in detail measuring distinct oscillations in its brightness during peak energy which are a crucial component in understanding giant magnetar flares. With the EHT, the structure of the magnetic fields at the edge of the black hole in M87 was imaged for the first time. Additionally, the EHT pinpointed the central black hole at the heart of the nearby galaxy Centaurus A. New results from SKA precursors (MeerKAT, ASKAP, LO-FAR, among others) with high resolution studies of galaxy groups and galaxies in the Local Group were published. IAA researchers led the study of I2V18, one of the most metal-poor galaxies, connecting the radiation which produces a Helium halo with the presence of Pop III stars. From the theoretical side, we could mention that the IAA participated in the development of Uchuu, the most accurate and complete simulation of the large-scale structure of the Universe. Regarding CAHA, the feasibility studies of the instruments TARSIS and GAMAICA were presented in Spring 2021 to the Calar Alto Scientific Advisory Committee (SAC). Both are Integral Field Unit (IFU) spectrographs and successfully passed the feasibility study phase, once evaluated by an Instrumental and Technical Advisory Committee. A final recommendation by the SAC, after an in-depth review of each project, would be sent to the new CAHA Executive Committee, which would take the final decision on the selected instrument. The Instrumental and Technological Development Unit (UDIT) develops state-of-the-art instruments for ground-based telescopes and space-borne astrophysical payload instrumentation. During 2021, the final electrical and thermal testing and assembly of the instruments Tumag and SCIP electronic units, scientific cameras and harness for Sunrise III was performed. Sunrise III mission is expected to be launched in June 2022. The flight models of the IAA’s contribution to the instruments GALA & JANUS for the JUICE mission were delivered for the integration in the spacecraft. JUICE mission is expected to be launched in 2023. UDIT also contributed to the instruments COCA, MANIAC, Enviss and OPIC for Comet Interceptor, VenSpec and VEM for EnVision, and PIM for Vigil (former Lagrange), and the MEUs for PLATO. With regard to ground-based instrumentation, UDIT contributed to new instrumentation for CAHA (CAR-MENES-PLUS), and the feasibility studies for GAMAICA and TARSISI and OSN (MIMA). A number of technical activities were performed at the OSN, including the mirror coating of the 90 cm telescope. IAA is also playing a relevant role in the ESFRI infrastructures for Astronomy. The Spanish Government initiated the necessary steps to become a member of the new IVO SKA. The IAA is coordinating the Spanish participation in SKA, with funds granted by a budgetary line from the Spanish Ministry of Science (2021). This reinforces the consolidation of the Spanish SKA office at the IAA. IAA is prototyping the Spanish node of the international SKA Regional Center (SRC) network, advocating for the principles of Open Science and reproducibility. For EST, our center leads the consortium for tunable imaging spectropolarimeters, one of the core instruments of which three units are planned to be built. For CTA, the IAA played an important role in the development of the Gammamap project, both from the point of view of software development and project governance. In 2021, CTA adopted the Gammamap software package for scientific analysis of the data produced at this observatory. For ELT, the official start of the two new instrumental projects for the ELT, ANDES and MOSAIC, both with IAA participation, was approved by the Council of the European Southern Observatory (ESO). Along 2021 the activity at the institute’s headquarters started returning into normal. One aspect that we would like to highlight is that the number of PhD theses defended increased substantially: in 2021, eleven theses were defended by IAA’s predoctoral researchers. Young researchers were particularly hard hit by the effects of the pandemic, which made the interaction with their supervisors difficult, prevented scientific exchange visits, and limited the discussion among the centre’s researchers to the screen in many cases. This large increase in the number of theses defended witnessed the return to a more normalised scientific life. A research institute grows and learns from all those who have worked in it. At the IAA we have incorporated into our year-end meeting a tribute to colleagues reaching retirement age. The combination could not be more interesting: the presentation of all the scientific, technological and outreach activities carried out at the IAA during the year (2021 in this case), together with the tribute to those who have contributed to make the IAA the center it is today. In December 2021 we paid tribute to our fellow scientists José Juan López Moreno and Víctor Aldaya, our UDIT colleagues Miguel Herranz de la Revilla and Luis Cosilillo, and our administrative colleague Rosa de Castro. This was not a goodbye, it was a see you always. Enjoy this Report.
IAA Organizational Chart

DEPARTMENTS
- Solar System: René Duffard
- Stellar Physics: Pedro J. Amado González
- Radio Astronomy & Galactic Structure: Emilio Alfaro Navarro
- Extragalactic Astronomy: Joseta Masegosa Gallego

SERVICE UNITS
- General services: Francisco Tapia Ruiz
- Outreach & Communication: Emilio J. García Gómez-Caro
- Instrumental & Technological Development Unit: María Balaguer Jiménez
- Computer Center: José Ruedas Sánchez

OBSERVATORIES
- Calar Alto (CAHA): Jesús Aceituno Castro
- Sierra Nevada (OSN): Maia García Comas

ADVISORY COMMITTEES
- External Advisory Board
- Institute Board

Picture group at the "IAA Day 2021", celebrated on December 17th.

From left to right: Luis Costilla, Miguel Herranz, José Juan López-Moreno, Rosa Castro, and Víctor Aldaya. All five retired in 2021.
IAA overview

The Instituto de Astrofísica de Andalucía (IAA) is the largest Astronomy institute of the Consejo Superior de Investigaciones Científicas (CSIC). The IAA research is supported by a number of research groups, covering most of the research topics in modern Astrophysics. This research is carried out within four different departments.

Research Groups

Solar System
- Solar Physics
- Planets and minor bodies
- Terrestrial Atmosphere

Stellar Physics
- Lowmass Stars
- Stellar Variability
- ARAE
- HETH

Radio Astronomy and Galactic Structure
- Stellar Systems
- PISM
- ADN jets

Extragalactic Astronomy
- Galaxy evolution
- Theoretical gravitation
- Observational Cosmology
- Cosmology and Astroparticle Physics

The Instrumental and Technological Development Unit (UDIT) and the Computer Center (CC) provide technical support to the research lines.

The IAA owns the Sierra Nevada Observatory (OSN) and is also the CSIC reference research center for the Calar Alto Observatory (CAHA).

Staff

262
Total member

Category and gender distribution

Permanent Staff (10 Female / 42 Male)

Predoctoral Researchess (15 Female / 31 Male)

Services (17 Female / 16 Male)

Electronics (21 Female / 4 Male)

Optics (6 Female / 2 Male)

Mechanics (5 Female / 2 Male)

Software (21 Female / 4 Male)

Postdoc contract (23 Female / 1 Male)

PhD contract (6 Male / 2 Female)

Research professor (10 Male / 1 Female)

Scientific researcher (19 Male / 4 Female)

Ramón y Cajal (4 Female / 1 Male)

MSC postdoc (1 Male / 1 Female)

MSC postdoc (1 Male / 1 Female)

MSC predoc (6 Male / 2 Female)

JAE-Intro (1 Female / 1 Male)

Postdoc (28 Male / 8 Female)

FPI (24 Male / 3 Female)

JAE-Intro (1 Male / 1 Female)

MSc predoc (6 Male / 2 Female)

PhD contract (11 Male / 4 Female)

Awards
- 4

Total budget
- 14.1 M€

2021 results

303
SCI publications

47
seminars at the IAA

43
press releases

18
meetings and schools

27
theses (PhD, Master, Degree)

17
courses

4
awards

14.1 M€
total budget
The IAA Severo Ochoa Programme

Isabel Márquez
Scientific Director SO-IAA Project

Straddling the third and final years of the Severo Ochoa IAA award, and in spite of the abnormal normality, the year 2021 came with a number of relevant results in different scientific areas. Among them, we led a number of studies that contributed to the understanding of planetary systems: an ambitious radio observation project that showed that extrasolar planets can be detected with radio telescopes and follow their variability. DARMENES allowed the detection of hot earths and super-earths in NGC1052, the discovery of a system formed by a white dwarf and a Jupiter-like planet showed that planets can survive the death of their stars, from the theoretical side, we first approached the problem of the distribution of temperatures on the surfaces of distorted white dwarfs, and thanks to the stellar occultation technique, we were able to determine the characteristics of an elongated centaur almost 400 km long. In the study of star formation in the Milky Way and the Local Universe, we led both the first evidence of a jet emerging from the central star of a planetary nebula, and the most extensive census of stars in the Galactic Center recorded to date. We also led a number of results on galaxy evolution and cosmology: we studied the distinct pulses in the giant magnetic flare from a neutron star, the most distant magnetar flare captured to date, located in the Sculptor group of galaxies; with EHT, we imaged the magnetic fields at the edge of the supermassive black hole in M87, we investigated the origin of the radiation producing the Helium halo around IZw18 and its eventual connection with PopIII stars; we detected a gas outflow emanating from the center of the Arp299 merging system with the unprecedented detail provided by LOFAR; we led the discovery of very low surface brightness galaxies in the environments of NGC1052, and the discovery of a possible satellite galaxy of M33.

The scientists. They provide a fair representation on the numerous projects with 85% of them in the first quartile (Q1), more than one third led by IAA numerical simulation UCHUU led by the we strongly participated in the generation of the virtual universe providing a perspective of the virtual universe; the discovery of a possible satellite galaxy of M33; the discovery of very low surface brightness galaxies in the environments of NGC1052, and the discovery of a possible satellite galaxy of M33; the discovery of very low surface brightness galaxies in the environments of NGC1052, and the discovery of a possible satellite galaxy of M33;

Concerning our protopype of SKA Regional Center, in 2021 it hosted 9 research and 9 development projects, together with 8 training activities; we highlight the set-up of the infrastructure to host the SKA Data Challenge 2, and the development of a distributed archive for the ASKAP Hill all-sky survey WALLABY. In February 2021, the council of the International Radio Astronomy observatory SKAID (Square Kilometre Array Observator)y intergovernmental organisation (IGO) was formed. The Spanish participation in SKA is led by the IAA-CSIC.

We continued our Web-loquio program (colloquia in virtual format), with more than 30 high standard talks, which were followed by numerous researchers also from other institutions in Spain and abroad.

Our visiting program started to recover, trying to overcome the difficulties for travelling even within Europe due to the pandemics. Our training activities, most of them in the online format, were significantly boosted. Among them I highlight the two Scientific Advanced Schools, on “Planets, exoplanets and their systems in a broad and multidisciplinary context” (fully online) and “Star Formation” (hybrid format), together with more than half of the total modules of our “Advanced School for Instrumentation”, the second editions of the schools for Machine Learning, Big Data, and Deep Learning in Astronomy, and Statistics and Data Mining, respectively. Overall, almost 100 teachers and 700 students participated in all the Severo Ochoa IAA training activities during 2021. We also strengthened our actions to recruit master students through the JAE-intro SOMM program, thanks to which we could welcome 7 master students who started their projects in the corresponding SO-IAA research fields.

Among our Gender programme activities, we highlight the virtual meeting with secondary schools organised for the International Day of Women and Girls in Science (February 11th), and the virtual round table “Women of excellence: meeting women Scientific Directors of Severo Ochoa Centers” (March 11th).

We also strongly contributed to the design and elaboration of the virtual exhibit “Astronomas” (www.astronomas.org). Concerning outreach, we participated in a number of activities related to the multifORMAT project “Hello Earth”, including a documentary, the edition of a desk-book and several concerts, at IAA, Calar Alto Observatory and CSIC Madrid, where the SD-IAA exhibit “Perspective” was shown to the public.

The SO-IAA personnel recruited in the previous year could introduce themselves in our IAA (Información y Actualidad Astronómica, nr 66) outreach journal.

We also celebrated an SO-IAA Conference in March 2021, together with a gathering of all SO-IAA committees in June and a welcome in-person meeting in September. We actively participated in the meeting 100xCiencia.5 organised by the Severo Ochoa and Maria de Maeztu Alliance (SOMMa), celebrated in Santiago de Compostela in November, and devoted to the International dimension of Science. In December we had the kick-off meeting for the preparation of the new Severo Ochoa proposal, to be submitted in February 2022.

Virtually all activities above were supported by the personnel at the SD-IAA Technical Office, hired under the SO-IAA auspices: Alicia Pelegrina, Head of the Office, and Manuel González, whose help was especially instrumental for the SO-IAA monitoring and visitor assistance. Their efforts were joint together with the IAA administrative personnel, with particular emphasis devoted to European projects and technology transfer.
Research groups

CSIC considers the research groups as specific fundamental units which contribute to achieving the scientific objectives of the institution.

During 2021, the IAA had 13 active research groups, which belong to the global area of "Materia". At the IAA we cover all major fields of Astrophysics and Space Science. Our research is based on the three pillars of modern Astrophysics: observation, instrumental development, and theoretical and numerical studies, all of which are firmly established and inter-connected. The IAA groups study:

- The Sun, via spectropolarimetry, and their magnetic fields from an observational, theoretical and instrumental point of view: "Solar Physics Group".
- The Earth’s atmosphere and planet atmospheres, including exo-atmospheric studies: "Group of Terrestrial Planet Atmospheres".
- Planets and the formation and evolution of minor bodies in the Solar System: "Planets and Minor Bodies Group".
- The physics of planetary systems and their low-mass stars: "Physics of low-mass stars, exoplanets and associated instrumentation Group".
- The variability of stars and asteroseismology: "Stellar Variability Group".
- Stellar clusters, massive stars and the Galactic Center: "Stellar Systems Group".
- The formation, evolution and death of stars at different mass and spatial scales and the interstellar medium: "Physics of the Interstellar Medium Group".

- The structure and evolution of galaxies, from the inner stellar and diffuse components to their large-scale cosmic distribution and evolution: "Galaxy Evolution Group".
- Supermassive Black Holes and their immediate environments, including their associated relativistic jets: "Relativistic Jets and Blazars Group".
- The combination between General Relativity and Quantum Mechanics in astrophysical scenarios: "Theoretical Gravitation and Cosmology Group".
- The analysis of large-scale galaxy clustering mechanisms and the production of accurate cosmological simulations and galaxy mock catalogs: "Cosmology and Astroparticle Physics Group".
- Multirange observations of high-energy phenomena and theoretical stellar evolutionary models: "High Energy Astrophysics and Robotic Astronomy Group (ARAE)".
- The radiative transfer equation (RTE) for polarized light in the presence of magnetic fields: "Theoretical Gravitation and Cosmology Group".
- The inversion of the RTE for its use on the interpretation of spectropolarimetric measurements: "The structure and physical nature of all kind of photospheric magnetic structures, The design, development, and construction of solar instrumentation.
- The formation, evolution and death of stars at different mass and spatial scales and the interstellar medium: "Physics of the Interstellar Medium Group".
- The physics of planetary systems and their low-mass stars: "Physics of low-mass stars, exoplanets and associated instrumentation Group".
- The variability of stars and asteroseismology: "Stellar Variability Group".
- Stellar clusters, massive stars and the Galactic Center: "Stellar Systems Group".
- The formation, evolution and death of stars at different mass and spatial scales and the interstellar medium: "Physics of the Interstellar Medium Group".

Overview

The IAA’s Solar Physics Group (SPG) focuses on solar spectropolarimetry from all the three points of view: theoretical, observational, and instrumental. Investigations and developments are carried out on:

- The radiative transfer equation (RTE) for polarized light in the presence of magnetic fields.
- The combination between General Relativity and Quantum Mechanics in astrophysical scenarios: "Theoretical Gravitation and Cosmology Group".
- The analysis of large-scale galaxy clustering mechanisms and the production of accurate cosmological simulations and galaxy mock catalogs: "Cosmology and Astroparticle Physics Group".
- Multirange observations of high-energy phenomena and theoretical stellar evolutionary models: "High Energy Astrophysics and Robotic Astronomy Group (ARAE)".
- The radiative transfer equation (RTE) for polarized light in the presence of magnetic fields: "Theoretical Gravitation and Cosmology Group".
- The inversion of the RTE for its use on the interpretation of spectropolarimetric measurements: "The structure and physical nature of all kind of photospheric magnetic structures, The design, development, and construction of solar instrumentation.

Research lines:

- Quiet-Sun and active regions: magnetoism.
- Magnetic coupling of the solar atmosphere.
- Diagnostic techniques in spectropolarimetry.
- Solar cycle.
- Solar instrumentation.

Highlights

Science

The analytical formulation of telecentric, Fabry-Pérot etalons was obtained [24].

Internetwork fields (INs) carry a substantial amount of magnetic flux, and therefore energy, to the solar surface. We used coordinated observations obtained with the Swedish Solar Telescope and the Interface Region Imaging Spectrograph to follow the evolution of IN magnetic loops [116].

We discussed the application of convolutional neural networks (CNNs) as a tool to advantageously initialize Stokes profile inversions. CNNs alone are much faster than assisted inversions, but the latter are more robust and accurate [97].

Instrumentation

SUNRISE III (TuMag & SCIP instruments)

- Final testing of SCIP E-Unit FM (electrical tests and thermal balance test).
- Further development of the SCIP E-Unit software and firmware and support to the NAOJ team for the instrument characterization and optical performance.
- Optical characterization and thermal balance test of the TuMag scientific cameras FM.
- TuMag E-Unit FM assembly and testing (electrical tests and thermal balance tests).
- TuMag E-Unit and O-Unit integration and AIV phase: calibration and end to end testing at INTA.
- TuMag instrument delivered to MPS.

SOLAR SYSTEM

Solar Physics

Top: transmission profiles (expressed in %) of an etalon in telecentric beams with f-numbers f/40 (blue), f/60 (green), and f/80 (red). Bottom: difference between the transmission profile calculated numerically and that obtained with the analytical expressions (expressed in %).

The following pages present a summary of the results obtained in 2021 by the different research groups. The publications corresponding to the different highlights are identified in brackets, with the corresponding number in the publication list (from page 68 on).
Overview

The activities of this group are focused on four research lines: planets, minor bodies, exoplanetary atmospheres, and the Cosmic Dust Laboratory (CoDuLab). Broadly speaking, we aim to provide an integrated view of the Solar System and the atmospheres around exoplanets. Observational projects are being conducted from the ground as well as by using instrumentation on board space vehicles. The data interpretation is based on theoretical modeling, numerical simulations, and laboratory studies. We are involved in a number of space missions such as BepiColombo, ExoMars, JUICE, Comet Interceptor, and EnVision.

Research lines

- Planets and minor bodies of the Solar System
- Dust in the Solar System
- Exoplanetary atmospheres

Highlights

Retrieval of gas and dust distribution of comet 8P/Tuttle, as a backup target for Comet Interceptor Mission. Comet Interceptor Mission is devoted to explore a dynamically new comet, but in the event that none of those objects becomes available while the spacecraft “waits” in the Sun-Earth Lagrange point L2, a number of short-period comets are being listed as alternative targets. Comet 8P is among those targets, and was characterised in [125].

Gathering Formaldehyde: We reported, for the first time, the detection of formaldehyde in the atmosphere of the brown dwarf LkCa 15B using the Gemini GTC telescope. We also provided the first discovery of formaldehyde in the atmosphere of a young hitherto-undetected brown dwarf, using the Gemini 8-meter telescope.

Establishing the spatial and temporal variability of iodine in aerosol. Aerosol iodine field observations in the period 1963-2018 were used to discuss its variability on the light of CAM-Chern model simulations [107].

Experimental determination of dust grain sizes from photopolarimetry. The direct comparison of the experimental data with computations for spherical particles showed that the use of the Mie model for analyzing polarimetric observations of cosmic dust clouds prevent locating particles with sizes of the order or larger than the wavelength of the incident light [201].

Image above:

Stellar occultation lightcurves of centaur 2002 QG293 obtained at the five sites where the occultation was recorded, ordered from the northernmost site (Kellie, Dunedin, Spain, bottom curve) to the southernmost one (University of Athens, Greece, top curve). The occulted star is Gaia DR1 4532865296837034896 (J/UCAC4 395-79221). See reference [201].

Solar System

Terrestrial and planetary atmospheres

Overview

We investigate the thermal structure, composition, chemistry, dynamics and electrically homogeneous and non-LTE models. We found very outstanding results for studying this hydrodynamic escape mechanism. We analysed Hey triplet measurements taken by CARMENES of the hot Jupiters HD 209458b and HD 189733b and the warm Neptune GJ3470b with developed hydrodynamic and non-LTE models. We found very outstanding results [164, 165]. See figure:

a) we reported, for the first time, observational evidence of the three hydrodynamic escape regimes in H-dominated atmospheres (photon-limited, energy-limited, and recombination limited), as theoretically predicted

b) the upper atmospheres of these planets are lighter than expected (H/He ratios much larger than that of the Sun); and

c) we provided unprecedented constraints on their mass loss rates and thermospheric temperatures.
Low-mass stars & exoplanets

Overview

Our group studies the physics of planetary systems and their low-mass host stars. M dwarfs are interesting by themselves and for their potential for the discovery of temperate rocky planets that could sustain liquid water. We work in several aspects of these systems, from the general statistics and observational distribution of their exoplanets to the astroseismological modelling and magnetic activity of their host stars. The group has expertise in theoretical studies of stellar structure and evolution, magnetic activity, astroseismology and technical development of new instrumentation. The group hosts the co-PI of the CARMENES consortium and one of the two PIs of the CARMENES Legacy-PLUS project.

Research lines

- Stellar structure and evolution of very low-mass stars
- Asteroseismology
- Exoplanets, Magnetic activity
- Astronomical instrumentation

Image above

Minimum mass of the planets detected around M dwarfs by other surveys (black symbols) and CARMENES (red symbols) plotted versus their respective orbital periods. The three star symbols show the planets detected in [13]. The shaded curves show the mass-period regions where it is not possible to detect other smaller or longer-period planets in the same datasets in that paper.

Highlights

CARMENES is a worldwide unique instrument, co-led by the IAA. It is collecting high-precision radial velocities simultaneously by its optical and the near-infrared channels. The latter was designed and built at the IAA and has shown to be a groundbreaking instrument for the study of exoplanet atmospheres, opening new lines of research in this field. It is the largest exoplanet survey of red dwarfs to date. In 2021, the CARMENES Legacy-Plus project continued enlarging and deepening the original survey.

CARMENES has published or submitted 87 papers, 21 of them in 2021, with 40 discovered or confirmed new planets and 15 additional firm candidates. This has allowed us to publish the first and most accurate statistical study on occurrences of exoplanets around M dwarfs to date. The CARMENES results have increased by 50% the number of planets in the parameter space probed by our instrument. In 2021, we continued leading the consortium and contributing to its working groups. We also continued our participation in the other large exoplanet survey in the southern hemisphere (RedDots) and in NASA’s mission TESS.

We continued discovering unique systems that deepen our understanding of close-in terrestrial and super-Earth planets, such as those in the systems G 264-012 and Gl 393 [13], the latter producing the smallest amplitude yet, which shows the precision we can reach with CARMENES. The CARMENES Legacy-Plus project continued enlarging and deepening the original survey.

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Stellar variability

Overview

The research at IAA’s Stellar Variability Group focuses mainly on the study of stellar structure and evolution and its impact on the characterization of exoplanets, stellar populations and galactic archaeology using astroseismological techniques. The group members are involved in the development of theoretical models as well as innovative time series analysis techniques that can be applied to extract information from ultra-precise data, especially observations from space satellites. Instrumental developments are the key part of the work of the group’s technical team. The group is also represented in the IAA Sky Quality Office.

In the past we participated in the design and exploitation of the CoRoT space mission and, currently, we are strongly involved in the preparation of the future PLATO 2.0 (ESA) space mission.

Research lines

- Stellar Structure
- Stellar Evolution
- Time Series Analysis
- Open Science

Highlights

Asteroseismology allows to study stellar interiors by analysing how oscillations (manifested at the surface of the star as brightness variations or Doppler shifts) propagate at different depths depending on their frequency. Delta Scuti stars are intermediate-mass (i.e. between 1.5 and 3 solar masses) pulsating stars which are moderate-to-fast rotators with spectral types ranging from A to F; these stars are very good laboratories to test theories of angular momentum and chemical transport in stellar interiors. The detection and understanding of rotation in stellar interiors is, nowadays, one of the main unsolved questions in stellar physics. Rotation severely hampers an accurate determination of stellar global parameters, such as effective temperatures and surface gravities. Although we have measurements of projected velocities, until now only interferometric techniques for bright and deformed stars may be able to determine the angle of inclination of the star and, therefore, the real rotation velocity.

In [241] we analysed the periodicities found between the pulsation frequencies of a sample of Delta Scuti stars using three well known techniques: the Fourier transform, the autocorrelation function and the histogram of frequency differences. We were able to identify the signature of the rotation (namely, the rotational splitting) in most of the cases, thus paving the way for developing a robust methodology to determine the rotation using astroseismic data only.

In the figure, we label as “delta r” the rotational splitting, which stands out as a prominent peak in all three analysis techniques.

Technological highlights of PLATO, where IAA is responsible for the MEU (Main Electronic Unit).

- Delivery of 2 units: MEU MTD (Mass Thermal Dummy) at OHB.
- MEU CDR (Critical Design Review) in progress.
Research lines:

- **Compact Objects in the Galaxy**
- **Cosmic Gamma-Ray Bursts (GRBs)**
- **Gravitational Waves (GW)**
- **Electromagnetic counterparts**
- **Robotic Astronomy**
- **Astrophysical Transients**

**Overview**

The ARAE research group was founded in 2001, although some of its members had already started their activity in 1990. Scientists and engineers work on a variety of projects, combining their strengths. Research lines are multi-range observations of high-energy phenomena, theoretical stellar evolutionary models and models of stellar populations' synthesis. Significant technological developments are also carried out, regarding the robotization of small-medium size observatories and astronomical instrumentation development such as the BOOTES Global network of telescopes. We are also involved at space-borne missions. Teaching, public outreach and citizen science are also part of the ARAE activities.

**Highlights**

**Study of the nearby \( z = 0.0785 \) VHE-detected GRB 190829A/SN 2019oyw** (135)

Gamma-ray bursts (GRBs) represent the most powerful explosions in the Universe, with the long-duration ones being related to massive star collapses. GRB 190829A is one of the most energetic events recorded to date. We presented the 10.4 m GTC observations of the afterglow of GRB 190829A and its underlying supernova (SN) and compared to GRB 180728A, similar in behaviour. We concluded that although the prompt emission temporal properties of GRB 190829A and GRB 180728A are similar, the two pulses are different in the spectral domain. The SN 2019oyw associated with GRB 190829A is powered by Ni decay and is a Type Ic Broad-Line SN, its spectroscopic and photometric properties are consistent with those observed for SN 1998bw, but evolved earlier.

**Very high frequency oscillations in the main peak of a magnetar giant flare** (55)

Magnetars are strongly magnetized, isolated neutron stars with high X-ray luminosities and very short rotation periods. Very energetic giant flares (lasting \(< 0.1 \) s) have been detected in hard X-rays/soft gamma-rays from magnetars, all but one detected from inside our galaxy. During such giant flares, Quasi-Periodic Oscillations (QPOs) with low and high frequencies have been observed, their significance been questioned. High frequency QPOs have only been seen during the tail phase of the flare. We reported the observation of two broad QPOs at very high frequencies in the main peak of a giant gamma-ray flare in the direction of the NGC 253 galaxy, disappearing after 3.5 ms. The flare was detected by the ASIM instrument aboard the International Space Station, the only instrument (8.1m Gemini South).

**Research lines:**

- **Explosive transients:** Gamma-ray bursts, supernovae, fast radio bursts, unusual objects
- **Electromagnetic counterparts** of gravitational waves
- **Host galaxies of astronomical transients:** Spatially resolved with IFU and unresolved
- **Starburst galaxies** from low to high-redshift
- **Very late evolution stages** of massive stars
- **New instrumentation:** OCTOCAM at Gemini, GATOS and EIFIS at GTC

**HETH**

**Overview**

The “High-Energy Transients and their hosts” (HETH) group studies stellar explosions and their environments. The main focus are gamma-ray bursts (GRBs) but the group also studies a wide variety of explosive transients such as supernovae, magnetars or tidal disruption events. HETH also develops new tools and instrumentation to enhance the research capabilities. Group members have been part of the teams developing instruments such as GROND (2.2m telescope, La Silla) or X-shooter (8.2m VLT, Paranal) and have led the OCTOCAM instrument (8.1m Gemini South).

**Highlights**

**Outflows from GRB hosts are ubiquitous: kinematics of \( z < 0.3 \) GRB-SN hosts resolved with FLAMES** (278)

GRB hosts studied with resolved integral field spectroscopy are still rare, due to the low numbers at suited (low) redshifts. This is the first sample of GRB hosts observed not only at high angular but also spectral resolution using the FLAMES/VLT spectrograph at a medium resolution of \(-10.000\). Our sample of six dwarf galaxies at \( z < 0.3 \) all show indications for powerful outflows from star-forming regions, a direct evidence for the massive star-formation happening in GRB hosts. Most galaxies in our sample do not show a regular rotating disk in the narrow component and, in some cases, even show a double component. The outflow component is more metal rich, blue-shifted compared to the narrow emission component and follows a different velocity field. Similar high-resolution studies for other explosive transients would be highly warranted to study resolved star-formation processes and effects on the galaxy.

**The Exotic Type Ic Broad-Lined Supernova SN 2018gep: Blurring the Line Between Supernovae and Fast Optical Transients** (238)

In the past few years, a new type of transient has emerged, called “fast blue optical transients” (FBOTs), some of which are related to supernovae. SN 2018gep was one of the most extreme of these FBOTs with very fast rise time and high peak magnitude and, after a featureless blue spectrum until peak magnitude, it evolved into a peculiar broadline Type Ic SN. The contribution from HETH was a spatially resolved study of the host galaxy of SN 2018gep through a DDT program at PMAS/CAHA. The galaxy is a star-forming dwarf and the SN located in a star-forming region with 0.4 solar metallicity, much below what has been measured for other BL-Ic SNe and very different from other FBOTs, giving further evidence for a peculiar type of BL-Ic and progenitor system.
**Stellar systems**

**Overview**
The Stellar Systems Group (SSG) was created in 1988. Our research lines cover stellar clusters, massive stars, and the Galactic Centre. Currently, the group is studying the connection between star-forming processes and spatial and kinematic structures at different scales, and continues with the exploitation of large Galactic surveys (including Gaia, DES, OTELO, GALANTE and J-PLUS). The second focus of our work lies on investigating the structure, kinematics, and formation history of the Galactic Center and massive star formation in this emblematic region of the Milky Way. Please visit our website for more information: https://ssg.iaa.csic.es/.

**Research lines**
- Galactic Centre
- Formation, evolution and destruction of Stellar Systems
- Massive Stars

**Highlights**
The Galactic Centre Team doubled the number of known stars with radio emission originating in ionized stellar winds in the 2-3 Myr-old massive Arches stellar cluster in the Galactic Centre in a combined near-infrared and radio study, that benefits from the high sensitivity of the Very Large Array [98]. The derived mass-loss rates of the observed massive post-main sequence stars agree well with those of Wolf Rayet stars, in agreement with their spectral identifications. By comparing the number of detected stars with their expected number inferred from stellar evolutionary models, the Galactic Centre Team found that the observations require that the Arches cluster formed relatively more massive stars than previous star formation processes in the Galactic disc. This finding of a so-called top-heavy initial mass function is an independent confirmation of theoretical predictions and of the results of previous near-infrared studies.

The Stellar System Group has as its main objective the study of the structure, formation and destruction of stellar systems. The astrometric and photometric data provided by Gaia represent the frontier, in quality and quantity, for this kind of studies. In addition, the group is involved in international consortia to obtain complementary data to Gaia that help us to achieve these scientific objectives, such as J-PLUS, GALANTE, WEAVE and 4-MOST to name just a few.

In 2021 we continued with the exploitation of the Gaia releases by analyzing the astrometric data in collaboration with other groups of the IAA, thus reinforcing the cohesion and synergy between the different lines of research of our institute. In particular, we analyzed the kinematics of the planetary nebula Sab 19 and determined its orbit in the Milky Way [120]. Within the GALANTE consortium, we published a paper about the design of the observational strategy, the selection of target fields, and the data reduction pipeline, which was applied to obtain the photometric catalog that we are preparing [181].

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**Relativistic Jets & Galactic Structure**

**AGN Jets**

**Overview**
The main research topic of our group is the study of supermassive black holes (SMBHs) harbored in the nuclear region of active galaxies. Huge amounts of energy are released from their innermost environment in the form of ultra-relativistic jets, as a consequence of mass accretion onto the SMBH and energy extraction through powerful twisted magnetic fields anchored to it. We study these objects at the maximum achievable angular resolution by means of very long baseline radio interferometric observations with the Event Horizon Telescope (EHT) and the space antenna RadioAstron. Thanks to these instruments, we are able to directly image SMBHs and the jets forming close to them.

**Research lines**
- Imaging supermassive black holes with the Event Horizon Telescope
- Accretion onto supermassive black holes and the formation of relativistic jets
- Blazar jet multi-wavelength phenomenology from the horizon to parsec scales
- AGN, black hole growth and demographics, binary blackholes and gravitational waves

**Highlights**
In 2017 April, the Event Horizon Telescope (EHT) observed the near-horizon region around the supermassive black hole at the core of the M87 galaxy. These 1.3 mm wavelength observations revealed a compact asymmetric ring-like source morphology. This structure originates from synchrotron emission produced by relativistic plasma located in the intermediate vicinity of the black hole. In two subsequent papers, published in 2021, we presented the corresponding linear-polarimetric EHT images of the center of M87 [8] and the theoretical interpretation [7]. This polarized synchrotron radiation probes the structure of magnetic fields and the plasma properties near the black hole. We found that only a part of the ring is significantly polarized. The resolved fractional linear polarization has a maximum located in the southwest part of the ring, where it rises to the level of ~15%. The low fractional linear polarization in the resolved image suggests that the polarization is scrambled on scales smaller than the EHT beam, which we attributed to Faraday rotation internal to the emission region. We showed that the net azimuthal linear polarization pattern may result from organized, poloidal magnetic fields in the emission region. In a quantitative comparison with a large library of simulated polarimetric images from general relativistic magnetohydrodynamic (GRMHD) simulations, we identified a subset of physical models that can explain critical features of the polarimetric EHT observations while producing a relativistic jet of sufficient power. The consistent GRMHD models are all of magnetically arrested accretion disks, where near-horizon magnetic fields are dynamically important.

In [95] we presented our latest RMHD and non-thermal emission simulations aimed to study the role of the magnetic field in the jet dynamics and emission. Models with the highest magnetizations and/or magnetic pitch angles lead to an uneven distribution of the internal energy as a consequence of the larger relative magnetic tension and radial Lorentz force, which translates into a spine brightening in the total and linearly polarized intensity maps. Highly magnetized jets with large toroidal fields tend to have weaker shocks and correspondingly weaker radio knots.

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**AGN**

**Overview**
The Stellar Systems Group is a group of astrophysicists that focuses on the study of the structure, kinematics, and formation history of the Galactic Center and massive star formation in this emblematic region of the Milky Way. The group is involved in international consortia to obtain complementary data to Gaia that help us to achieve these scientific objectives, such as J-PLUS, GALANTE, WEAVE and 4-MOST. In 2021, the group continued with the exploitation of the Gaia releases by analyzing the astrometric data in collaboration with other groups of the IAA. In particular, the group analyzed the kinematics of the planetary nebula Sab 19 and determined its orbit in the Milky Way. Within the GALANTE consortium, the group published a paper about the design of the observational strategy, the selection of target fields, and the data reduction pipeline, which was applied to obtain the photometric catalog that is currently being prepared.

**Research lines**
- Galactic Centre
- Formation, evolution and destruction of Stellar Systems
- Massive Stars

**Highlights**
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The Stellar System Group has as its main objective the study of the structure, formation and destruction of stellar systems. The astrometric and photometric data provided by Gaia represent the frontier, in quality and quantity, for this kind of studies. In addition, the group is involved in international consortia to obtain complementary data to Gaia that help us to achieve these scientific objectives, such as J-PLUS, GALANTE, WEAVE and 4-MOST. In 2021, the group continued with the exploitation of the Gaia releases by analyzing the astrometric data in collaboration with other groups of the IAA. In particular, the group analyzed the kinematics of the planetary nebula Sab 19 and determined its orbit in the Milky Way. Within the GALANTE consortium, the group published a paper about the design of the observational strategy, the selection of target fields, and the data reduction pipeline, which was applied to obtain the photometric catalog that is currently being prepared.
Research lines

- Massive stars and their surroundings. SN remnants and wind-blown bubbles
- Star and planet formation and interaction
- Planetary nebulae and their precursors
- Luminous and Ultra-Luminous Infrared Galaxies
- Prospective Science work for the SKA

Overview:

We study the formation, evolution, and death of stars at different mass and spatial scales across different environments. The early stages of star and planet formation, as well as star-planet interactions, are studied through radio interferometric observations and modelling of the observed emission. The final stages of the life of stars are studied by the multi-wavelength monitoring of supernova (SN) explosions and their precursors, and wind-blown bubbles around them, to understand the processes shaping planetary nebulae and the circumstellar medium around massive stars. Radio interferometric monitoring of supernova (SN) explosions and their distribution in ultra luminous infrared galaxies is also carried out to determine the SN and star formation rates.

Highlights

Planetary nebulae (PNe) are expected to expand and brighten notably in its early formation phases, but the comparison of the images of the Stingray Nebula (aka Hen 3-1357) captured by HST in 1996 and 2016, revealed exactly the opposite: the nebula dimmed drastically in brightness and it seems to have shrunk [27]. This is interpreted as a response to a drop of the surface temperature (and therefore, of ionizing radiation), of its central star, SAO 244567, after a brief flash of helium fusion. These results demonstrate that nebular changes in PNe can occur on human time-scales.

The jet in NGC 2392, the Head’s Lion Nebula, was the first ever detected in a PN, but an image of the jet was lacking because its terribly weak emission is projected against bright nebular emission. GTC MEGARA observations allowed imaging this jet for the first time [118]. At odds with the fossil jets in other mature PNe, the jet in NGC 2392 is currently being collimated and launched, supporting the presence of a double-degenerate system where one component undergoes accretion.

We carried out the most comprehensive radio monitoring campaign towards the closest star to our Sun, Proxima Centauri, using the ATCA [227]. We detected radio emission from the star and its planet, Proxima b, showing periodic emission enhancements synchronized with the orbital planetary motion. This radio emission is powered by electron cyclotron-maser, which is able to provide strong, pulsed-like, polarized emission. The data agree very well with the predictions from models of interaction between a host star and its planet. This pioneering work shows, for the first time, that the presence of an exoplanet can be detected by observing periodic variations of radio emission from the system, opening a new path for the detection and study of exoplanets. This is a very promising technique given the exceptionally sensitive radio telescopes that are currently under development, such as the SKA.

Overview

Our group is interested in theoretical gravity, both at the classical level and specially on those situations in which General Relativity (GR) - the best theory of gravity we have- is expected to start failing. The most promising situation in which to observe departures from GR is the physics of gravitational collapse and its end result (black holes in the standard theory). Thus, a large part of our research is centered in analyzing how different situations in standard GR would be modified when going beyond this theory. For instance, we analyze modifications based on semiclassical gravity and those suggested by emergent and analogue gravity scenarios. We study the viability of the new scenarios suggested by these frameworks.

Highlights

Structure of gauge theories [10]. This works contains a complete description of how the crucial notion of gauge symmetry can be most clearly understood embedded into a group theoretical setting. This allows, for example, to fix the Weinberg theta angle algebraically. In addition, it suggests the possibility of a direct non-perturbative quantization of massive non-Abelian Yang-Mills fields without recurring to the Higgs mechanism.

Semiclassical constant-density spheres in a regularized Polyakov approximation [19]. Semiclassical (SC) gravity is a gravitational theory beyond General Relativity which takes into account effects of vacuum polarization. When a stellar configuration approaches the black hole limit, these SC effects become so relevant that they can largely deform the classical geometry. In this paper we proved that SC gravity can lead to relativistic stars so compact that they can be mistaken by black holes.

Black hole inner horizon evaporation in semiclassical gravity [31]. We analyze SC effects at the inner horizon that any realistic black hole contains. We show that the inner horizon has a tendency to move outwards and that this tendency is exponential. This suggests a change of paradigm for black hole evaporation: instead of a slow decay from the outside in, it points towards the possibility of a fast decay from the inside out.

Toward a Mechanism for the Emergence of Gravity [29]. We present a mechanism through which gravity could emerge from an underlying system akin to condensed matter systems. We discover a way to avoid confronting the two most important obstacles faced by emergent gravity: Weinberg-Witten’s and Marolf’s theorems. Our mechanism relies on making gravity emerge at the same time than the diffeomorphism gauge symmetry characteristic of general relativity.

Interpretations and naturalness in the radiation-reaction problem [32]. We revisited the one-century-old conceptual problem of understanding when and how a classical charge radiates and how this radiation back-reacts on its trajectory. This revision allowed us to introduce an additional turn in the usual analysis: the natural trajectories of regular extended charges should exhibit an oscillating behaviour.
Galaxy Evolution

Overview

The group conducts observational and theoretical studies over a wide variety of issues on galaxy structure and evolution, and cosmology. These range from the inner stellar and gaseous components of galaxies to their large-scale cosmic distribution and evolution. These are complemented with the participation in the research and development of instrumental and technological projects. Observationally, data from 2D spectroscopy, multi-band photometric and HI surveys are used for studies that include the physics of star formation, stellar populations and the diffuse medium in galaxies and galaxy groups and clusters, nuclear activity in galaxies and their interplay with stellar evolution, or the environmental dependence of the structure and evolution of galaxies. These activities include supervising PhD, teaching at master and doctoral level, public outreach conferences, and eScience. Furthermore, we are leading since 2011 the participation of Spain in SKA. Furthermore, we are leading since outreach conferences, and eScience.

Highlights

Chemical abundances in the nuclear region of nearby galaxies from the Palomar Survey (224).

We have estimated chemical abundances and ionization parameters in the nuclear region of a sample of 143 galaxies from the Palomar Spectroscopic Survey, composed of star-forming galaxies (87), Seyferts 2 (16), and LINERs (40) using the HII-CHI-MISTRY code. We correlated the derived quantities with different properties of the host galaxies, such as morphology, stellar mass, luminosity, and mass of their supermassive black holes. We find that Seyferts 2 present slightly higher chemical abundances. In contrast, we obtain lower chemical abundances for LINERs than for star-forming galaxies. Our analysis of AGNs (both LINERs and Seyferts) shows that their host galaxy properties are not correlated with our estimated chemical abundances.


The Javalambre-Physics of the Accelerated Universe Astrophysical Survey (J-PAS) will observe 8000 deg2 of the northern sky with 56 photometric bands, and is ideal for the detection of emission line galaxies. We have developed a new method based on artificial neural networks to measure the equivalent width (EW) of Hα, Hβ, [N II], and [O III] lines up to z = 0.35. These lines are essential diagnostics for understanding the evolution of galaxies through cosmic time. We trained and tested artificial neural networks with synthetic J-PAS photometry from CALIFA, MaNGA, and SDSS spectra. We prove the capability of the method by recovering the BPT (II/III)/Hβ versus [N II]/Hα and WHAN (EW/Hα) versus [N II]/Hα diagram reaching a precision of 0.092 and 0.078 dex for the [N II]/Hα and [O III]/Hβ ratios. Furthermore, we show the capability of the method to measure an EW of 10 Å in Hα, Hβ, [N II] and [O III] lines with a signal-to-noise ratio (S/N) of 5, 1.5, 3.5, and 10, respectively, in the photometry. Finally, we compare the properties of emission lines in galaxies observed with miniJ-PAS and SDSS. Despite the limitation of such a comparison, we find a remarkable correlation in their EWs.

The miniJ-PAS survey. Identification and characterization of a sample of galaxies from the miniJ-PAS photometric system (112).

We present the potential of J-PAS by the identification and characterization of a sample of galaxies from the miniJ-PAS photometric system (112). SED-fitting codes are used to constrain the stellar mass, age, metallicity, extinction, and rest-frame dust-corrected [u − r] colours of a complete flux-limited sample in 22.5 AB of galaxies that extends up to z = 1. For galaxies with S/N > 10, we estimate that the J-PAS photometric system will allow us to derive the galaxy properties with precisions that are equivalent to those obtained with spectroscopic surveys of similar S/N. We find: (i) that the fraction of red and blue galaxies evolves with cosmic time, with red galaxies being ~38% and ~18% of the whole population at z = 0.1 and z = 0.5, respectively, and (ii) at all redshifts, the more massive galaxies belong to the red sequence, and these galaxies are typically older and more metal-rich than their counterparts in the blue cloud. Our results confirm that with J-PAS data we will be able to analyze large samples of galaxies up to z ~ 1, with galaxy stellar masses above log(M⋆/M⊙) ~ 8.3. Constrained by the nuclear region of a sample of 143 galaxies from the Palomar Spectroscopic Survey, composed of star-forming galaxies (87), Seyferts 2 (16), and LINERs (40) using the HII-CHI-MISTRY code. We correlated the derived quantities with different properties of the host galaxies, such as morphology, stellar mass, luminosity, and mass of their supermassive black holes. We find that Seyferts 2 present slightly higher chemical abundances. In contrast, we obtain lower chemical abundances for LINERs than for star-forming galaxies. Our analysis of AGNs (both LINERs and Seyferts) shows that their host galaxy properties are not correlated with our estimated chemical abundances.

The challenge of the ionization balance of Helium II in IZw18 (147).

IZw18 is a champion among the most metal-poor (−4%) Z⊙ galaxies known in the Universe. We have unveiled the existence of a strong H-shell-emitting region in this galaxy, thus representing a unique local analog of the most distant HII objects found towards the cosmic dawn. The source of ionization of the observed IZw18 H-shell region remains a mystery, since it could not be explained invoking only the conventional stellar sources for this galaxy. This is the first study of the X-ray variability of IZw18, which has been performed in order to evaluate the contribution of the X-ray photons from the dominant high mass binary (HMXB) of IZw18 to the ionization of the region of Hell. The X-ray emission of the galaxy is found to show small variations on timescales from days to decades. The best-fit to the observations using models of HMXB X-ray spectra with photoionization models (Souchay et al. 2020) cannot explain the Hell ionization budget of IZw18, so the Hell ionization challenge remains.
Overview
The Instrumental and Technological Development Unit (UDIT) is focused on the development of state-of-the-art instruments for ground-based telescopes and space-borne astrophysical payload instrumentation. During more than 40 years, the instruments developed at the UDIT have placed the IAA as a reference center for technological research projects.

The technical production at the UDIT can be split into two major lines:

• Analysis, design, integration, and verification of astronomical instruments for ground-based telescopes in Calar Alto Observatory (CAHA), Sierra Nevada Observatory (IOMS), ELT (Extremely Large Telescope), etc.
• Analysis, design, integration, and verification of astronomical instruments for interplanetary scientific space missions and stratospheric balloon observatories.

Highlights
In the following a summary on the activities performed during 2021 for the instrumentation projects that were developed at the UDIT is provided.

Space projects

JUICE (JUpiter ICy moons Explorer). The Flight Models (FM) of the IAA’s contribution to the instruments GALA and JANUS were delivered for integration in the spacecraft, these are the Power Converter Module (PCM) of the instrument GALA and the power supply and mechanisms control module (PSM and MCM respectively) and the filter wheel of the instrument JANUS. The mission is expected to be launched in 2023.

Comet Interceptor: The technical team worked in the design and manufacturing of several prototypes (EBB) to reach the Technology Readiness Level (TRL) 5. The IAA is responsible for developing the power converter modules for the instruments COCA and MANIAC as well as the power-handling unit and the data handling unit for the instruments Envisis and OPIC.

EnVision: The IAA worked on the preparation of the CoDR documentation package for the power supply of the suite of instruments Venus Spectroscopy (Venspec) and VEM (Venus Emission mapper).

PLATO (PLAnetary Transits and Oscillation of stars): The technical team was focused on the manufacturing and verification of the Mass Thermal Dummy (MTD) of the two MEU (Main Electronics Unit) that were successfully delivered at the end of 2021. In addition to this, the team worked in the integration of the MEU engineering model with the rest of the subsystems of the instrument. The development of the instrument Qualification Model (QM) and the Critical Design Phase also started during this period.

SUNRISE III: The final electrical and thermal testing and assembly were performed for the instruments TuMag and SCIP electronics units, scientific cameras and harness. Software and firmware development for both instruments also continued. During 2021, calibration and end to end testing of both instruments was carried out with the direct implication of IAA’s technical team. Sunrise III mission is expected to be launched in June 2022.

Vigil (former Lagrange): The IAA technical team finished the pre-development study for the PMI instrument Digital Processing Unit (DPU) with the definition of a conceptual design for this subsystem. The design of a DPU Development Model (DM) started, which will be the starting point to reach TRL 6. In addition to this, the definition of the PMI electronics, harness and grounding concept started.

Solar Orbiter: Technical activities were devoted to support PHI Solar Orbiter operations.

Ground-based instruments:

MOSAIC (Multi-object spectrograph for ELT): The first hardware prototype was manufactured to perform the testing of the updated version of the instrument control software. The technical team also worked on the definition of the next step prototype, based on a multi-axis test bench and was focused on management aspects like the development tools definition, budgets, work-packages description, etc.

New instrument for the 3.5m telescope in CAHA: The UDIT concluded in 2021 the feasibility studies of two potential instruments for CAHA observatory next generation instrumentation: GAMAICA and TARIS.

GAMAICA: The IAA participated in the instrument concept development including structural and front-end mechanical and opto-mechanical designs, electronics and software designs and spectrograph fiber system unit conceptual design.

TARIS: The IAA contributed to the instrument concept development with the electronics and instrument control software conceptual designs.

Other CAHA instrumentation: In 2020 the UDIT had continued to work on the instrument PANIC (Pano-ramic Near Infrared Camera for Calar Alto) through the adaptation of the instrument software to the new detector.

MIMA (Multi-Spectral Imager Metaspace Airglow): The instrument reached its final development phase. The software and electronics were integrated and the AIV phase started. The instrument commissioning and the first light is expected in 2022.

GALIUS (GrAnada Lightning Ultrafast Spectrograph): With the work performed in 2021, two papers were published. One of them describes the experimental analysis of the radial profile of a lightning-like plasma channel through high-speed spectroscopy, which was done for the first time. In addition to this, the group also recorded green signatures of a real sprite.

Data Science: This group’s activities were focused on the development of algorithms to be executed in computational clusters for autonomous image calibration, precision astrometry in Gaia EDR3, absolute photometry and light curves generation and cross-correlation between catalogs enabling the use of artificial intelligence.
Activities and highlights

Overview

CAHA is a key institution for the international astronomical community, for its highly competitive astronomical facilities (telescopes and instrumentation). From 2019 on, the Spanish National Research Council (CSIC) and the Junta de Andalucía manage the operation of the observatory with the same percentage. The IAA-CSIC is the research institute of reference of the observatory.

Publications and main scientific results

Observations at Calar Alto produced in 2021 a total of 107 publications in international peer-reviewed journals. This includes both scientific projects awarded with open time, and the long-term legacy projects that started in 2021. Calar Alto also continued its activities for the development of new instrumentation, as well as basic infrastructures. We describe below the most relevant of these activities:

Two new planetary systems orbiting G 264-012 and Gliese 393, containing super-Earths, were discovered with the high-resolution spectrograph CARMENES at the 3.5m telescope. This result, reinforces the idea that low-mass stars are susceptible to be orbited by terrestrial planets. Although the high temperatures of the new discovered planets prevent the presence of liquid water in their surface, this discovery has implications for the study of the probability of life in the Universe [13].

CARMENES observations also allowed the characterization of a planet surrounding the star Gliese 486. The combination of the properties of the planet and its distance to the star make it observationally favorable for searches for an atmosphere [284].

Studies of exoplanetary atmospheres with CARMENES led to the first detection of atomic and molecular oxygen in the planet orbiting the star Kepl-9. This is the hottest exoplanet known, thus unsuitable to harbor life (Borsa et al. 2021, Nature Astronomy, 6, 226-231).

The study with CARMENES of the planets orbiting the star V1298 Tauri suggests that the gaseous giant planets could evolve much faster than expected from the current models that point to a slow formation of giant planets (Suárez Mascareño et al. 2021, Nature Astronomy, 6, 232-240).
Three telescopes at Calar Alto (3.5m, 2.2m, and 1.23m) participated in an ambitious observational campaign aimed at studying the clouds of the Venus atmosphere and their relation to its observed variability. This project is being carried out by an international consortium that includes researchers from the País Vasco University; it combines data from different spatial missions and ground telescopes, and among the varied instrumentation used to gather the data, we highlight the camera PlanetCam, available at Calar Alto (Lee et al. 2021, EPSC, 15, 637).

The European Space Agency (ESA) agreed a collaboration with Calar Alto that aims at studying Near Earth Objects including Potentially Hazardous Asteroids. This project not only provides an important service to the ESA Planetary Defense Office, but also produces relevant results related to other astronomical topics. A good example was the discovery of the cataclismic and eclipsing type DQ Herculis binary star, a system with a variety of peculiarities that make it unique (Beuermann et al. 2021, Astronomy & Astrophysics, 657, A101).

Calar Alto also participated in an interdisciplinary initiative (C-CLEAN) that includes several research institutes. This project is intended to detect viruses on surfaces. A prototype, patented at Sevilla University, applies hyperspectral images to detect the characteristic signal of several microorganisms, like fungi, bacteria and viruses (including SARSCoV-2), as well as their concentration (108).

**International collaborations**

OPTICON is an European network dedicated to share optical astronomical resources at a European level. During 2021, OPTICON joined RadioNet, its equivalent in Radioastronomy. This resulted in the OPTICON-RadioNet (ORP) network, the largest collaborative network of ground-based astronomy in Europe, which intends to coordinate methods and observational tools, and to provide access to a wider set of astronomical facilities. Calar Alto, previously part of OPTICON, participates now in ORP, together with the IAA-CSIC, Cambridge University (United Kingdom), CNRS (France), and Max-Planck Institute of Radioastronomy (Germany), among others.

The ongoing international long-term observational projects continued during 2021:
- The project SEAMBH (Super-Eddington Accreting Massive Black Hole), in collaboration with Beijing University, is dedicated to the study of supermassive black holes in active galactic nuclei applying the reverberation method, using the CAFOs instrument at the 2.2m telescope.
- The extragalactic survey CAVITY (Calar Alto Void Integral field Treasury survey), devoted to the study of the properties of galaxies in cosmic voids, the loneliest objects in the Universe. This project makes use of the integral field spectrograph PMAS at the 2.2m telescope.
- The KOBES survey is searching for potentially habitable exoplanets orbiting K-dwarfs, and is using the CARMESEN spectrograph at the 3.5m telescope.
- The MERCENES Legacy+ is an extension of the CARMESES survey, and is intended to the detection and characterization of planets around M-dwarfs, the occurrence of long-period giant planets, and the characterization of exoplanet atmospheres.

**New technological developments**

The construction of the prototype MARCOT Pathfinder started in 2021. This project proposes to create large optical telescopes by adding the light collected by many small individual telescopes, coupled through innovative technological concepts. The MARCOT collaboration includes Calar Alto, IAA-CSIC, and Potsdam Astronomical Institute (Germany).

During 2021, it started the execution of the first phase for the installation of a Fabry-Pérot calibration unit for the CAFÉ high-resolution spectrograph at the 2.2m telescope. This action will further improve the already excellent performance of this instrument.

CAHA was searching for a new instrumental concept to be developed for its flagship telescope, the 3.5m. This concept will be selected from the instrumental ideas that were presented during a science workshop for Calar Alto held at IAA-CSIC in March, 2020. Two designs were selected for the viability study phase: TARSIS and GAMAICA. The final decision on the instrument selected to proceed to the construction phase is expected for Spring 2022.

Also related to the CARMESEN spectrograph, the CARMESEN+ project started the actions on the hardware to improve the thermal stability of the Near Infrared arm of the instrument, which is critical to obtain the optimal spectral resolution that makes this instrument unique.

Finally, regarding basic infrastructures, the project of improving the energy management in the observatory executed most of the civil work during 2021. This initiative was funded by the FEDER program (Reference ICT5-2017-CAHA-4) and by the Programa de Ayuda a ICT5 del subprograma estatal de infraestructuras científicas y técnicas y equipamiento (reference CAHA-16-CE-3798).
OSN
Sierra Nevada Observatory

Overview
OSN is a high mountain observatory located at 2896m in the Sierra Nevada National Park. It belongs to CSIC and is operated by the IAA. It houses two optical telescopes with 1.5m and 90cm apertures, named T90 and T150. Like many other medium-sized astronomical observatories, the OSN compensates the limited access to observing time at large observatories by providing great flexibility to serve programs that require rapid response or intense temporal coverage, either in terms of sampling or extension. Indeed, OSN focuses on covering long-term follow-up and target of opportunity programs, currently in support of the IAA’s research lines. Its privileged location also makes it an ideal site for mid-upper atmosphere sounding and as a test bed for external instrumentation.

Highlights
The T90 and T150 telescopes were equipped with two 4Mp cameras in 2021. The Alireo spectrograph and the Strømgrem photometer were undergoing technical actions. OSN also housed the SATI spectrometer, dedicated to the study of the mesopause region, and instrumentation from IAA’s Sky Quality Office. OSN also hosted external equipment, namely, a meteoroid detection station and a GPS station. Among the activities, we highlight:

Observation programs
Observations from the OSN have proven very useful for exoplanetary transits. Measurements of transit depths of 1.2 mmag at T90 and extraordinary accuracies of 0.73 mmag (rms/min) at T150 were possible. OSN hot Jupiter TRES-5 b transit observation allowed to conclude that its orbital period varies on a long timescale, likely due to the orbital motion induced by a wide-orbiting massive companion [178].

OSN CARMENES target follow-ups were key to characterizing M dwarf stars and discarding false exoplanet detection positives. It facilitated CARMENES discovery of two planetary systems of Earths and super-Earths orbiting GJ393 and G264-012, allowing to constrain their masses and periods to 1.7ME and 7-day period for the planet around the former, and 2.5 and 3.8ME and 2.3 and 8.1 days period for the planets around the latter [13].

Centaur and TNO occultations observed from OSN were used to constrain the properties and probabilities of rings around Solar System minor bodies. 2002GZ32 centaur occultations resulted in a negative detection of thick rings, as the ones found for Chariklo, but narrower or optically thinner rings could not be ruled out [261].

Other programs running at OSN included the SN2 project, focused on building a spectro-photometric sample of type-Ia supernovae; blazar polarimetry and photometry to contribute to the MAGIC and WEBT collaborations; the monitoring of comet 67P/Churyumov-Gerasimenko to understand its evolutionary processes; the follow-up of Gamma Ray bursts to study their temporal evolution; and the contribution to CoRoT legacy, to test properties scaling relations of δ Scuti stars.

Main Technical Activities
In a coordinated UDIT and OSN effort, the three T90 mirrors were transferred to CAHA for aluminization in September after silver M3 coating removal. After their alignment in record time, the signal on the T90 improved by 80%.

A new low dark noise and high quantum efficiency CCD, identical to and interchangeable with that at T150 and also not requiring liquid N2, was installed at T90.

External collaborations
• SMART Project (Univ. Huelva), analyzing the interplanetary material impacting our planet with five robotic cameras at OSN.
• L3AmetSurf Project (Univ. Granada), testing samples to study material properties and in search for patentable anti-icing solutions.
• Topo-Iberia station (Univ. Barcelona), a GPS station used for integrated studies on topography and 4-D evolution.
• STNS StarTracker Project (Solar-Mems), a sensor-based pointing subsystem for nano and micro-satellites tested at OSN.
• Master in Astronomy and Astrophysics (Valencia Intl’ Univ.), for which observing practices are carried out under an agreement.
The ESFRI initiatives

The IAA vis-à-vis the ESFRI initiatives in Astronomy

The European Strategy Forum on Research Infrastructures (ESFRI) was established in 2002 at the request of the European Council, with the aim of coordinating a common strategy on scientific facilities and research infrastructures and, in particular, develop a Pan-European Infrastructure Roadmap. The IAA participates actively in all the astronomy-related scientific facilities included in the last updated Roadmap (https://roadmap2021.esfri.eu/).

Square Kilometer Array (SKA)
The Square Kilometre Array (SKA) is an international project to build the world’s largest radio telescope. Thanks to its extraordinary sensitivity, SKA will be able to conduct transformational science, breaking new ground in astronomical observations. Two relevant events took place in 2021 for the SKA, and the IAA was part of them. The first SKA Observatory’s (SKAO) Council meeting was held in February, following the establishment of the SKAO as the world’s second intergovernmental organization (IGO) dedicated to astronomy. IAA is coordinating the Spanish participation in the SKA project, and is part of the Spanish Delegation in this and subsequent Councils. On the other hand, after a historical meeting of its Council, the SKAO Member States approved the start of the construction phase of the SKAO’s telescopes. As part of this construction, Spain was pre-allocated several contracts related to band receivers, timing distribution and dish manufacture, with IAA’s contributing to the associated negotiations. On the other hand, as one of the strategic projects within our Severo Ochoa grant, IAA is prototyping the Spanish node of the international SKA Regional Center (SRC) network, advocating for the principles of Open Science and reproducibility. The development of the SRC includes aspects such as the development of the necessary hardware and software platform, the scientific and technical support to users from the IAA-CSIC, or the establishment of collaborations with national and international centers.

Cherenkov Telescope Array (CTA)
The Cherenkov Telescope Array (CTA) will be the global astronomical very-high-energy (VHE) gamma-ray observatory that will exceed the performance of existing instruments in terms of angular resolution, energy coverage and field of view. It will provide a sensitivity improvement of about an order of magnitude over any previous experiment. In June 2021, Gammapy was selected as the CTA (Cherenkov Telescope Array) Science Tool, a software package for the scientific analysis of the CTA data. Moreover, Gammapy plays an integral role in the science operation workflows of the CTA Observatory itself, as part of the pipelines for science verification. For CTA, the IAA had a leading role on the development of the Gammapy project, both by participation in the Coordination Committee (that takes the high level decisions of the project), and by taking part in the group of main Gammapy developers.

European Solar Telescope (EST)
The European Solar Telescope (EST) will be the largest solar telescope in Europe. With a 4.2-meter primary mirror and state-of-the-art technology, it will provide astronomers with a unique tool to understand the Sun and how it determines near-Earth space weather conditions. In 2021, the project continued preparatory activities for construction, focusing efforts on the design of the telescope and its instruments: the tunable imaging spectropolarimeters, the integral field spectropolarimeters, and the multi-conjugate adaptive optics system. The IAA leads the consortium for tunable imaging spectropolarimeters, one of the core instruments, of which three units are planned to be built. The IAA coordinates the communication office of EST.

European Large Telescope (ELT)
Since 2005, ESO has been developing the Extremely Large Telescope (ELT), a revolutionary ground-based telescope that will have a 39-meter main mirror, making it the world’s largest visible-light and infrared telescope. In 2021, the official start of the Phase B of two new instrumental projects for the ELT, ANDES and MOSAIC, both with IAA participation, was approved by the Council of the European Southern Observatory (ESO). ANDES is a very high resolution multi-object spectrograph that will use the widest possible field of view provided by the ELT and will have three modes of operation covering observations in visible and infrared light for more than one hundred sources simultaneously. In 2021, the first MOSAIC hardware prototype was manufactured to perform the testing of the updated version of the instrument control software.
Sky Quality Office (OCC-IAA)

Overview
The OCC was created in 2016 as an instrument to preserve the astronomical sky quality at the Sierra Nevada and Calar Alto observatories against the threat of light pollution. Due to an increase of night sky brightness in recent years, the office aims at serving as a scientific reference for institutions and agents in the protection and improvement of the dark sky, in addition to advising and promoting the best practices for correct outdoor lighting. Illuminating properly and sustainably is essential to preserve the nocturnal ecosystem and minimize the harmful effects to human health. To monitor the sky brightness, the OCC has installed different types of photometers at the Sierra Nevada Observatory and at the IAA buildings.

Highlights and Activities
Research: Several scientific papers were published in 2021 on the study of light pollution from satellite images and RGB photometry for its calibration [52,53,74,257]. We highlight the article on the effects of the COV-ID-19 lockdown on urban light pollution in Granada between March and May 2020 [44], which has already more than 25 citations in international journals during the first year of publication. We found a clear decrease in light pollution due both to a decrease in light emissions from the city and a decrease in anthropogenic aerosol content in the atmosphere which resulted in a decrease of scattered light. Using ground and nighttime satellite data, a clear correlation between the abundance of PM10 particles and sky brightness is observed at three different wavelength bands. A more exhaustive analysis of this relationship was presented in a Master thesis in Astronomy and Astrophysics (Bustamante-Calabria).

Institutional collaborations: After carrying out a preliminary study on the feasibility of obtaining a night sky quality certificate in the territory of the Granada Geopark, in March 2021 a collaboration contract was signed with the Granada Provincial Council. At the beginning of the year, the Calar Alto Observatory joined the OCC with the incorporation of a member of the observatory. Representing the Sierra Nevada Observatory and together with Calar Alto, the office submitted a series of allegations for the approval of the new Andalusian regulation for protection against light pollution.

The participation in educational and outreach activities is one of the main tasks of the OCC with the aim of raising public awareness on the problem of light pollution. In 2021 we contributed with talks, scientific monologues and radio programs. It was important the participation of office members as teachers at the 2021 summer course on astro-tourism organized by the Andalusian International University.

New equipment: A TESS-4C multicolor photometer was acquired to measure the sky brightness at the Sierra Nevada Observatory. This instrument, equipped with GRB filters, serves as complement to the ASTMON (All-Sky Transmission MONitor) and the 4 SQM (Sky Quality Meters) devices with Johnson-Cousin filters already existing in the observatory building.
Public Outreach

The activities of the IAA-CSIC Communication, Education and Public Outreach Unit cover almost all existing formats to communicate science.

Popular Science Journal IAA: Información y Actualidad Astronómica. Issued once every four months, it is devoted to high school and university students, as well as general public interested in astronomy. Issues in 2021: 63, 64, 65.

Desgranando Ciencia science festival, co-organized by the IAA.

The European Researchers’ Night takes place every year all over Europe the last Friday of September. The IAA-CSIC took part in the event in Granada on Friday 24.

PIILSA Project. A multidisciplinary project designed to allow high school students to work with scientists. The IAA-CSIC is the founder of the project.

Course “Astrophysics in the classroom” for primary and secondary school teachers in collaboration with the Granada Teacher Training Centre (CEP Granada).

PRE-EST project (European Solar Telescope). Communication support and recording of the documentary “Reaching for the Sun” [in production].

Revista Astronomía. The IAA maintains a monthly collaboration with the magazine, the only one with a commercial circulation specialised in astronomy.

Lucas Lara outreach talks. These conferences began in 1995. We celebrate nine talks every year.

Double urban campaign on the solar system. The campaign in Granada’s tram cars “Tenemos cerca lo que está muy lejos” and the street marketing circuit “GRANADA ¡DESPEACIO”.

El Radioscopio, a weekly popular-science radio program in collaboration with Canal Sur Radio and broadcasted by Radio Andalucía Información.


Organization of the IV course on Science Outreach Techniques in collaboration with “Hablando de Ciencia” association, and participation in different courses and workshops about science communication.

Perspectiva. Exhibition on Astronomy for the CSIC headquarters in Madrid, related to “Hola Tierra” activities.

Pilares e incertidumbres. IAA-CSIC audiovisual project in which we talk about what we do not know about the universe.

La soledad del navegador. Ciencia y resiliencia. Project that combines science and the performing arts to promote reflection on isolation and adaptation, and their importance in various scientific fields. It targets groups that have suffered particularly badly from confinement during the pandemic.

Calar Alto Observatory Communication. The IAA-CSIC Communication, Education and Public Outreach Unit helps develop communication strategies and press releases for the observatory.

Alfonso X. El rey que quiso ser astrónomo. A show developed by the IAA on Astrophysics and History, with twenty-five voices, six musicians, two actors, and a 6x4 metre projection.

Camino a Congreso. Audiovisual project that is committed to a new format, the music webseries, which combines fiction, science outreach and music. Six episodes.

Astronomía Accesible. A multidisciplinary musical, poetic and humanist project. The project is based on the collection of poems entitled Hello Earth [1974], in which the Apollo 15 astronaut Al Worden described his experience in space, and includes the publication of a book, a CD and a documentary. The IAA participated in this initiative through the “Severo Ochoa - IAA” excellence award.

Pilares e incertidumbres. IAA-CSIC audiovisual project in which we talk about what we do not know about the universe.

La soledad del navegador. Ciencia y resiliencia. Project that combines science and the performing arts to promote reflection on isolation and adaptation, and their importance in various scientific fields. It targets groups that have suffered particularly badly from confinement during the pandemic.

¿Qué hacen las mujeres ingenieras en ciencia? A roundtable discussion, as an activity for the International Day of Women in Engineering (June 23).
The research activity carried out at the IAA-CSIC during 2021 can be measured by the number of publications in scientific journals included in the Science Citation Index (SCI), i.e., international journals recognized by their quality and impact. In 2020, this activity resulted in 303 papers published in journals of the SCI.

The complete list of the IAA-CSIC publications in 2021 is given in the Annex at the end of this report. The evolution of the number of SCI publications since 2015 is shown below. Along the years, the number of publications fluctuates around an average value of 275 papers per year.

The publications of the IAA-CSIC are mostly distributed in high impact journals. About 85% of our publications appeared in journals of the first quartile (top 25% journals, or Q1). Among these publications, 7% appeared in the first decile (top 10% journals, or D1). Most of the IAA-CSIC scientific results are published in Astronomy & Astrophysics and Monthly Notices of the Royal Astronomical Society, the main European astronomical journals. A significant fraction of our results is published in Astrophysical Journal, the most important American astronomical journal.

Another aspect of the scientific research of the IAA and its quantitative results is the leadership of these publications. In about 17% of the IAA SCI 2020 publications their first author belongs to our institute. This is consistent with the leadership of the IAA in the last 5 years.

### Number of publications by journal

<table>
<thead>
<tr>
<th>Journal</th>
<th>Publications</th>
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<tbody>
<tr>
<td>Astronomy and Astrophysics</td>
<td>82</td>
</tr>
<tr>
<td>Monthly Notices of the Royal Astronomical Society</td>
<td>72</td>
</tr>
<tr>
<td>Astrophysical Journal</td>
<td>26</td>
</tr>
<tr>
<td>Astrophysical Journal Letters</td>
<td>13</td>
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<tr>
<td>Astronomical Journal</td>
<td>9</td>
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<tr>
<td>Icarus</td>
<td>8</td>
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<tr>
<td>Geophysical Research Letters</td>
<td>7</td>
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<tr>
<td>Astrophysical Journal Supplement Series</td>
<td>6</td>
</tr>
<tr>
<td>Nature Astronomy</td>
<td>5</td>
</tr>
<tr>
<td>Experimental Astronomy</td>
<td>4</td>
</tr>
<tr>
<td>Journal of Geophysical Research, Atmospheres</td>
<td>3</td>
</tr>
<tr>
<td>Journal of Geophysical Research, Planets</td>
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<tr>
<td>Physical Review D</td>
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<tr>
<td>Atmospheric Measurement Techniques</td>
<td>1</td>
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<tr>
<td>Journal of Quantitative Spectroscopy and Radiative Transfer</td>
<td>1</td>
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<tr>
<td>Solar Physics</td>
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<tr>
<td>Universe</td>
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<tr>
<td>Nature Science Advances</td>
<td>1</td>
</tr>
<tr>
<td>Atmospheric Chemistry and Physics</td>
<td>1</td>
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<tr>
<td>Atmospheric Research - Space</td>
<td>1</td>
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<tr>
<td>Classical and Quantum Gravity</td>
<td>1</td>
</tr>
<tr>
<td>Journal of Geophysical Research, Space Physics</td>
<td>1</td>
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<tr>
<td>Remote Sensing</td>
<td>1</td>
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<tr>
<td>Symmetry</td>
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<tr>
<td>Others</td>
<td>1</td>
</tr>
</tbody>
</table>
Workshops & meetings

Meetings

Asymmetrical Post-main-sequence Nebulae 8 e2021: The Shaping of Stellar Outflows
INTERNATIONAL CONFERENCE
Granada, Oct 04 - 08, 2021 (virtual format)
IAA MEMBERS OF THE LOCAL ORGANIZING COMMITTEE: M. Guerrero Roncel
http://apn8.iaa.csic.es

PLATO Mission Conference 2021
INTERNATIONAL CONFERENCE
Granada, Oct 11 - 15, 2021 (virtual format)
IAA MEMBERS OF THE SCIENTIFIC ORGANIZING COMMITTEE: R. Garrido Haba, J. Suárez Yanes
IAA MEMBERS OF THE SCIENTIFIC ORGANIZING COMMITTEE: R. Schoedel
IAA MEMBERS OF THE LOCAL ORGANIZING COMMITTEE: A. Pelegrina López, M. González García
http://platomissionconference2021.iaa.es/

Horizon Europe: Workshop on RESEARCH INFRASTRUCTURE
NATIONAL WORKSHOP
Granada, Jun 09 - 09, 2021 (virtual format)
http://www.juntadeandalucia.es/actualidad/eventos/detalle/217675.html

Atmospheres, Atmospheres! Do I look like I care about atmospheres? (Atmo 2021)
ESO CONFERENCE
August 23-27, 2021 (Virtual)
IAA MEMBERS OF THE ORGANIZING COMMITTEE: Camilla Danielsky
https://www.eso.org/sci/meetings/2021/Atmo2021.html

Schools

Planets, exoplanets and their systems in a broad and multidisciplinary context
Granada, Jan 18 - 29, 2021 (virtual format)

IAA Severo Ochoa Advanced School on Star Formation
Granada, Nov 15 - 19, 2021
IAA MEMBERS OF THE ORGANIZING COMMITTEE: R. Schoedel, A. Pelegrina López, M. González García
IAA MEMBERS OF THE LOCAL ORGANIZING COMMITTEE: R. Schoedel
https://www.granadacongresos.com/starform

SO instrumentation school
Module I: High level synthesis for Xilinx FPGAs using Vivado HLS
Granada, Apr 28 - 30, 2021 (virtual format)
https://forms.gle/PkPmAhSyDxzwSTPA

Module II: Ansys Workbench for Scientific Instrumentation
Granada, Jun 10 - Jul 01, 2021 (virtual format)
https://forms.gle/PkPmAhSyDxzwSTPA

Module III. Beckhoff Motion Control
Granada, Sep 20 - 23, 2021
https://forms.gle/JSvV58VkJZKv65z7A

Module IV. Vacuum Technology
Granada, Oct 20 - 22, 2021
https://forms.gle/Aq5MdzcDu9Y22H

Module V. Project management in the 3DExperience environment, including document and requirements management
Granada, Nov 15 - 19, 2021 (virtual format)
https://docs.google.com/forms/d/e/1FAjQQLz5pU9-yjDRmra6HlEcuAWEunFf7gqmxMqAID8DBlb9EnoCnCq/viewform

Module VI. A practical introduction to Project Management and Earn Value Management for scientists, engineers and new project managers
Granada, Nov 29 - Dec 03, 2021 (virtual format)
https://forms.gle/gjgym8NLJ2DoyQOA

SOMACHINE 2 Machine Learning, Big Data, and Deep Learning in Astronomy
Granada, Apr 19 - 23, 2021 (virtual format)
IAA MEMBERS OF THE ORGANIZING COMMITTEE: R. Schoedel
IAA MEMBERS OF THE LOCAL ORGANIZING COMMITTEE: A. Pelegrina López, M. González García
http://www.granadacongresos.com/somachine2021

2nd IAA-CSIC Severo Ochoa School on Statistics, Data Mining, and Machine Learning
Granada, Nov 29 - Dec 03, 2021
IAA MEMBERS OF THE ORGANIZING COMMITTEE: R. Schoedel, A. Pelegrina López, M. González García
http://www.granadacongresos.com/sostat2021

Matplotlib for Beginners -
An introduction to IFU Spectroscopy
Granada, Jun 14 - 14, 2021 (virtual format)
https://forms.gle/TxWbil5UIa1TMiM8

Scientific writing and presentation in astronomy
Granada, Jun 09 - 10, 2021 (virtual format)
IAA MEMBERS OF THE ORGANIZING COMMITTEE: R. Schoedel, M. Pérez Torres
https://forms.gle/1TBbNA4J7BU4xApA

IV Course on Scientific Dissemination Techniques
Granada, Sep 15 - 16, 2021
https://granada.hablandodeciencia.com/cursos/

English for Academic Purposes -
an online workshop series for young researchers
Granada, Jun 21 - 25, 2021 (virtual format)
https://forms.gle/sQFPUJMN9pEFFrTA

Spanish for beginners at the IAA-CSIC
Granada, Oct 21, 2021 - Jan 22, 2022
Overview

The IAA is supporting inclusive initiatives in Gender Equality. This trajectory crystallized in the creation of the Institute’s Gender Equality Commission and the preparation and approval of the First Gender Equality Plan of the IAA-CSIC (GEP), in 2018. Here we present the main activities carried out in 2021. The Equality Commission continued its work of advising on the necessary or appropriate measures to actively integrate the principle of gender equality between women and men in the daily life of the centre, as well as in organizing events to raise awareness of the role of women in science.

Highlights

In addition to ensuring the gender equality measure, the Gender Equality Commission of the IAA-CSIC acts as the Gender Working Group of the gender equality plan drawn up by the Severo Ochoa project. All their governance bodies verify the gender equality, and the following actions have been contemplated:

1) Hypatia of Alexandria Visiting Grant: 2 visits of the visiting researchers program, out of the 6 offered, were given to female researchers.
2) Vera Rubin Colloquium: 14 colloquia, out of the 30 offered, were presented by female researchers.

Gender Activities in 2021 in the center

• Production of the annual statistics segregated by gender.
• Organization of activities for the International Day of Women and Girls in Science (11 February). Different informal meetings with women researchers, engineers and technicians at the IAA were held for the educational centers in Granada, with the aim of highlighting the role of women in science. These meetings included open discussions, individual reflections and questions about gender roles and the existing stereotypes around science, technology and engineering. We counted with the participation of Isabel Bustamante, Alice Deconto, Carolina Kherig, Luisa Lara, Mariel Lanes, Susana Martín, Alicia Pelegrina, Rosario Sanz, and Yolanda Teja, from the IAA, as well as students from 3rd course of ESO of IES Lanjarón and the CEIP Abencerrajes and CEIP Alcazaba (11-12 years old). Both activities were done on-line.

We also collaborated with the students of the Liceo Cervantes of Roma within the activity “¿Esta pregunta es para mí?” producing four videos where Sara Cazzoli, Laura Hermosa, Maria Passas and Mónica Vara answered their questions.

• Organization of activities for the International Women’s Day (8 March): We organized a round table under the title “Mujeres de Excelencia” with the participation of three female researchers who lead the Excellence Severo Ochoa project in their centers, namely María Blasco (CNIO), Isabel Márquez (IAA-CSIC) and Teresa Moreno (IDAEA-CSIC). It was chaired by Margarita Sánchez, Vicecouncilor of the Universidad de Granada.

• For the day of Women and Girls in Engineering (23 June), a round table was organized with the participation of the female engineers Beatriz Aparicio, María Balaguer, Isabel Bustamante, Carmen Pastor, Susana Sánchez and Rosario Sanz.

• Outreach activities:
Lourdes Verdes-Montenegro participated in a round table on the gender perspective in international R&I, organized by the Vicepresidency of International Relations of the CSIC.

Collaboration with the CSIC delegation in Andalusia in the “Moby Dick” podcast: Mayra Osorio, Alicia Pellegrina, Malide Fernández and María Passas. Seven lectures by women researchers from the IAA at the European Researchers’ Night 2021 and the “Desgranando Ciencia” event.

Production and distribution of the webseries “Camino a Congreso” in which the personal and working conflicts of women in science are one of the main drivers.

We continued to collaborate with scientific outreach magazines and the newspapers El País, Granada Hoy and Ideal. In the IAA magazine Información y Actualidad Astronómica, several articles were published with the aim of making visible female scientists who have contributed significantly to the development of Astronomy.

• Gender Equality and COVID-19 Questionnaire: An online evaluation survey was launched on October 22nd 2020 among IAA-CSIC members to collect data on the impact of the COVID-19 health crisis actions taken at work. The results were published in March 2021.

• CSIC Gender Equality Commission Meetings: We participated in the second meeting of the CSIC Gender Equality Commissions in November 17th organized by the IFT-CSIC in coordination with the CSIC Gender Equality Commission and in the meeting “Los planes de igualdad en los centros de investigación: intercambio de buenas prácticas”, organized by ICM in November 23rd.

• SOMMA Gender Equality Commission Meetings: In 2021 the SOMMA Gender Working Group was re-activated and we participated in the five online meetings organized along the year. As a result of these working meetings, a survey of the SOMMA centers was elaborated. Moreover, the second SOMMA Gender Working Group event took place in a hybrid format on May 26th, with the participation of the CSIC and the Science Ministry.
The Inaugural 2021 Jocelyn Bell Burnell Inspiration Medal was awarded to Mirjana Pović (ESSTI and IAA-CSIC) for "her work on developing astronomy, science and education as a route out of poverty and to improve the quality of life for young people in Africa".

Rocco Lico, a postdoc hired under the Severo Ochoa IAA project, was recognised with an EHT Early Career Award for "his dedication and positive contribution to the EHTC’s management processes and strategy, recognising his unique talent for combining management activities and innovative science".

Isabel Márquez was awarded in the “Women and Science” category of the "Granada City of Science and Innovation" 2021 awards, highlighting the fact that "not only does she embody the overwhelming force of someone researching in truly complex fields of knowledge, but she also combines this professional facet with activities to promote and raise awareness of the role of women in the truly vast field of astronomy”.

The Scientific Culture Unit of the IAA-CSIC (UCC) was awarded in the category of “Scientific Dissemination”. The UCC was highlighted for its “experience in pioneering activities in all possible languages and formats, which has undoubtedly contributed to the positioning of the IAA-CSIC as a national reference centre in the field of outreach”.

Funding

IAA obtains most of its funding through competitive European and Spanish grants (a total of 7.2 million € was obtained in the 2021 competitive calls).

During 2021, IAA managed a total budget of 14.1 million €, from which 6.8 million € (48%) came from competitive projects and CSIC investments; the other 7.3 million € (52%) corresponded to the permanent staff total cost and common expenses.

The yearly evolution of the IAA budget in the last 5 years is shown below, including the different concepts.
Staff

Assigned research group
- Solar Physics
- Planets and minor bodies
- Terrestrial atmosphere
- Low-mass stars
- Stellar variability
- ARAE
- HETH
- Stellar systems
- Physics of the interstellar medium
- AGN jets
- Galaxy evolution
- Theoretical gravitation and cosmology
- Observational cosmology
- Cosmology and particle physics

Research Professors
- Alberdi Odriozola, Antonio María (9)
- Castro Tirado, Alberto Javier (10)
- del Toro Iniesta, José Carlos (11)
- Garrido Haba, Rafael (10)
- González Delgado, Rosa María (11)
- López Puertas, Manuel (10)
- Pérez Jiménez, Enrique (11)
- Prada Martínez, Francisco (11)
- Vilchez Medina, José Manuel (11)

Scientific Researchers
- Aceituno Castro, Jesús (11)
- Alfaro Navarro, Emilio Javier (10)
- Anglada i Pons, Guillem Josep (11)
- Bellett Rubio, Luis Ramón (9)
- Funke, Bernd Rainer (10)
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- Schröder, Rainer (10)
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Senior Scientists
- Agudo Rodríguez, Juan Iván (10)
- Amado González, Pedro José (10)
- Barceló Serín, Carlos (10)
- Cisneros Santoso, Antonio (10)
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- López Jiménez, Antonio Carlos (11)
- López Valverde, Miguel Ángel (10)
- Luque Estepa, Alejandro (10)
- Miranda Palacios, Luis Felipe (10)
- Muñoz Gómez, Olga (10)
- Olivares Martín, José Ignacio (10)
- Perea Duarte, Jaime David (10)
- Rodríguez Gómez, Julio Federico (10)
- Ruedas Sánchez, José (10)

Ad honorem
- Aldaya Valverde, Víctor (10)
- López Moreno, José Juan (10)

Research Advisor
- Rodríguez Espinosa, José Miguel (10)
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<thead>
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<tr>
<td>Dur.</td>
<td>Jun 01, 2021 - Sep 30, 2022</td>
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<tr>
<td>Title</td>
<td>Ateca: Gas y campos magnéticos en entornos extremos de galaxias con los precursores de SAGA - desde el diseño del flujo de datos hasta su construcción</td>
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<td>Ampliar los horizontes del Hubble al máximo</td>
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<td>Experiencias de laboratorio, observaciones y modelos de polvo</td>
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<td>cometary: Una nueva estrategia</td>
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<td>Física de los objetos transneptunianos y poblaciones relacionadas</td>
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<td>Astronomía de rayos gamma con MAGIC y CTA-NORTE - contribución del</td>
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<td>AGN, del universo local a distancias cosmológicas. Del motor central</td>
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<td>a la galaxia anfífron y su entorno</td>
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<td>Física oculta en la evolución en tiempo real de las nebulosas gaseosas</td>
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<td>Proyecciones físicas del polvo cometary y aplicaciones biomédicas</td>
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<td>Explorando la formación y supervivencia planetaria en condiciones</td>
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<td>EXPLORANDO LA FORMACIÓN Y SUPERVIVENCIA PLANETARIAS EN CONDICIONES</td>
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</table>
EUROPEAN PROGRAM FUNDS

**Title**: e-LIGHTING: Lightning propagation and high-energy emissions within coupled multi-model simulations  
**Ref.**: 681257 (ERC-2015-COG)  
**PI**: Alejandro Luque Estepa  
**Dur.**: Jun 01, 2016 - May 31, 2021

**Title**: Preparatory Phase for the European Solar Telescope (PRE-EST)  
**Ref.**: 79500 H2020-INFRA/0247  
**PI**: Luis Ramón Bellot Rubio  
**Dur.**: Apr 01, 2017 - Dec 31, 2021

**Title**: Science and Innovation with thunderstorms (SAINT)- H2020-MSCA-ITN-2016  
**Ref.**: H2020-MSCA-ITN-2016  
**PI**: Francisco José Gordillo Vázquez  
**Dur.**: Mar 01, 2017 - Feb 28, 2021

**Title**: ROG and impAct of Dust and clouds in the Martian Atmosphere: from lab to space (ROADMAP)  
**Ref.**: 01004052 H2020-LEIT-SPACE/0753  
**PI**: Olga Muñoz Gómez  
**Dur.**: Nov 01, 2020 - Oct 31, 2023

**Title**: CICLE -- Unveiling the formation and evolution of galaxy clusters through the intracluster light and multidisciplinary techniques of image processing and big data analysis  
**Ref.**: H2020-MSCA-IF-2019 -- 898633  
**PI**: Yolanda Jiménez Teja  
**Dur.**: Apr 01, 2020 - Mar 31, 2022

**Title**: SOLARNET - 824135- Integrating High Resolution Solar Physics - H2020  
**Ref.**: 824135  
**PI**: Luis Ramón Bellot Rubio  
**Dur.**: Jan 01, 2019 - Dec 31, 2022

**Title**: ESCAPE-European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures  
**Ref.**: 83046 - H2020-INFRA/0489  
**PI**: Lourdes Verdes-Montenegro Atalaya  
**Dur.**: Feb 01, 2019 - Jul 31, 2022

MINISTERIO DE CIENCIA E INNOVACIÓN

**Title**: Coordination of the participation scientific and technological of Spain in the Square Kilometre Array. Oficina española del SKA.  
**Ref.**: 201950E125  
**PI**: Lourdes Verdes-Montenegro Atalaya  
**Dur.**: Dec 01, 2019 - Nov 30, 2022

**Title**: Ayuda del MICINN para la coordinación de la participación en SKA-españa  
**Ref.**: OTR07653  
**PI**: Lourdes Verdes-Montenegro Atalaya  
**Dur.**: Jan 01, 2021 - Dec 31, 2021

FECyT

**Title**: Horizontes de Luz  
**Ref.**: FCT-20-15889  
**PI**: Emilio José García Gómez-Caro  
**Dur.**: Jul 01, 2021 - June 30, 2022

CDTI

**Title**: Convenio CSIC-CDTI para la ejecución del Proyecto «Modelos de Vuelo para la MEU (Unidad de la Electrónica Principal) de PLATO»  
**Ref.**: ICTP-2010005  
**PI**: Julio Federico Rodríguez Gómez  
**Dur.**: Dec 06, 2021 - Dec 05, 2026

**Title**: Disk and jets in the formation of multiple stellar systems  
**Author**: Ana Karla Díaz Rodríguez  
**Sup.**: Guillam Josep Anglada i Pons  
**Univ.**: Universidad de Granada  
**Date**: Feb 10, 2021

**Title**: Numerical investigation on the advance of leader channels in lightning and long sparks  
**Author**: Alejandro Francisco Malagón Romero  
**Sup.**: Alejandro Luque Estepa  
**Univ.**: Universidad de Granada  
**Date**: Mar 23, 2021

**Title**: Characterisation of exoplanetary upper atmospheres undergoing hydrodynamic atmospheric escape  
**Author**: Manuel Lampión González-Albo  
**Sup.**: Manuel López Puertas  
**Univ.**: Universidad de Granada  
**Date**: Mar 24, 2021

**Title**: Properties of galaxies in galaxy clusters up to a redshift of z ~ 1  
**Author**: Zeleke Beyoro Amado  
**Sup.**: Solomon Tessema Belay, Mirjana Povic, Miguel Sánchez Portal  
**Univ.**: Ethiopian Space Science and Technology Institute (ESSSTI)  
**Date**: May 31, 2021

**Title**: Non-linear terms in Delta Scuti stars power spectra  
**Author**: Mariel Lares Martiz  
**Sup.**: Rafael Garrido Haba, Javier Pascual Granado  
**Univ.**: Universidad de Granada  
**Date**: Jun 11, 2021

**Title**: Spectropolarimetric and imaging properties of Fabry-Perot etalons. Applications to solar instrumentation  
**Author**: Francisco José Bañón Martínez  
**Sup.**: Jose Carlos del Toro Iniesta, David Orozco Suárez  
**Univ.**: Universidad de Granada  
**Date**: Jun 25, 2021

**Title**: Position on the Hertzsprung-Russell diagram of magnetically active young stars  
**Author**: Estefania Casal López  
**Sup.**: Matilde Fernández Hernández  
**Univ.**: Universidad de Granada  
**Date**: Jul 02, 2021

**Title**: High angular resolution radio observations of luminous infrared galaxies  
**Author**: Naim Ramírez Olivencia  
**Sup.**: Antonomitis Maria Aliberti Odnicola, Miguel Ángel Pérez Torres  
**Univ.**: Universidad de Granada  
**Date**: Jul 05, 2021

**Title**: e-LIGHTING: Lightning propagation and high-energy emissions within coupled multi-model simulations  
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**PI**: Lourdes Verdes-Montenegro Atalaya  
**Dur.**: Feb 01, 2019 - Jul 31, 2022

**Title**: Coordination of the participation scientific and technological of Spain in the Square Kilometre Array. Oficina española del SKA.  
**Ref.**: 201950E125  
**PI**: Lourdes Verdes-Montenegro Atalaya  
**Dur.**: Dec 01, 2019 - Nov 30, 2022
Búsqueda de galaxias de bajo brillo superficial en el entorno de galaxias masivas cercanas

Antonio Parazelli Bonidia

Dr. David Martínez Delgado

Valencia International University

10 Noviembre 2021

Clasificación morfológica de corrientes estelares

Juan Emiliano Vojarano Bolívar

Dr. David Martínez Delgado

Valencia International University

28 Junio 2021

Trabajo Fin de Master

Máximo Bustamante Calabria

Valencia International University

05/07/2021

DEGREE Thesis

Gradiencia de metalicidad del gas en galaxias barradas de baja masa

Silvia García Soto

Isabel Pérez & Rubén García-Benito

Universidad de Granada

21-07-2021

Courses

Analysis of integral-field spectroscopic data

Rubén García-Benito [IAA]

Seminarios de Investigación del Master de Astrofísica

Universidad Autónoma de Madrid

05-11-2021

Medio interestelar

Enrique Pérez Jiménez, Angeles Díaz, Elena Terlevich

Páster en Física Teórica

Universidad Autónoma de Madrid

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Modern Observational Techniques in Astronomy

Mirjana Povic

MSc y PhD

Ethiopian Space Science and Technology Institute, Ethiopia

Dec/2020-Marzo/2021 y Nov/2021 - Feb/2022

Stellar interior and evolution, and radiation measurements in astrophysics

Mirjana Povic

MSc

Ethiopian Space Science and Technology Institute, Ethiopia

Dec/2020-Marzo/2021

Observational Techniques in Astronomy

Mirjana Povic

MSc and PhD

Ethiopian Space Science and Technology Institute, Ethiopia

3 credit hours (6 ECTS)

April/2021-June/2021

Introduction to Astrophysics

Mirjana Povic

MSc/PhD

African School of Physics (ASP)

6

July/2021
**Title:** Técnicas Observacionales en Astrofísica  
**Teach.:** Simon Verley, Alberto Javier Castro Tirado, Martin Guerrero Roncel  
**Prog.:** Master en Física y Matemáticas [FISyMAT]  
**Univ.:** Universidad de Granada  
**Hours:** 30  
**Date:** February-June 2021

**Title:** The XXI century radio observatory: the Square Kilometer Array (SKA)  
**Teach.:** Javier Moldón  
**Prog.:** Máster Universitario en Astronomía y Astrofísica  
**Univ.:** Valencia International University  
**Hours:** 2  
**Date:** 02/12/2021

**Title:** Astrobiología y planetas extrasolares.  
**Teach.:** M. López Puertas  
**Prog.:** Máster Universitario en Física: Radiaciones, Nanotecnología, Partículas y Astrofísica  
**Univ.:** Universidad de Granada  
**Hours:** 10  
**Date:** May 2021

**Title:** Radioastronomía  
**Teach.:** Jose Francisco Gomez, Guillen Anglada, Antonio Alberdi, Angela Gardini  
**Prog.:** Master en Física y Matemáticas [FISYMAT]  
**Univ.:** Universidad de Granada  
**Hours:** 60  
**Date:** September 2020-March 2022; September 2021-March 2022

**Title:** Otros Sistemas Solares: Nacimiento planetario  
**Teach.:** Mayra Osorio  
**Prog.:** El sistema solar y la exploración espacial en el aula: potenciando nuevas vocaciones científicas  
**Org.:** Consejería de Educación y Deporte, Junta de Andalucía  
**Hours:** 2  
**Date:** 5 April 2021- 30 May 2021

**Title:** Origen y evolución de los elementos químicos en el Universo. Parte II.  
**Teach.:** Jose Manuel Vilchez Medina  
**Prog.:** Máster Universitario en Física: Radiaciones, Nanotecnología, Partículas y Astrofísica  
**Univ.:** Universidad de Granada  
**Hours:** 10  
**Date:** 7-21 March 2021

**Title:** Física de detectores  
**Teach.:** Jorge Iglesias Páramo [IAA-CSIC]  
**Prog.:** Máster Universitario en Física: Radiaciones, Nanotecnología, Partículas y Astrofísica  
**Univ.:** Universidad de Granada  
**Hours:** 15  
**Date:** November 2021

**Title:** El Cielo desde Sierra Nevada  
**Teach.:** Jose Manuel Vilchez Medina  
**Prog.:** Sierra Nevada: naturaleza y recursos  
**Univ.:** Universidad Internacional de Andalucia, UNIA  
**Hours:** 6  
**Date:** 6-9 September 2021

**Title:** Aproximación a la Astronomía  
**Teach.:** Miguel Pérez-Torros  
**Prog.:** Programa de formación para mayores de 55 años y jubilados  
**Univ.:** Universidad de la Experiencia de Zaragoza  
**Hours:** 20  
**Date:** March-May 2021

**Title:** Cosmicology and Galaxies  
**Teach.:** Mar Basteiro and Emilio J. Alfaro  
**Prog.:** Master Universitario en Astronomía y Astrofísica  
**Univ.:** Valencia International University  
**Hours:** 14  
**Date:** July- October 2021

**Press releases**

Access to all news at:  

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**Oxygen found in the atmosphere of the hottest known exoplanet**  
22/12/2021  
A team with the participation of the IAA-CSIC published the discovery of oxygen atoms in KELT-9b, the first detection of this compound in an exoplanetary atmosphere.

**Distinct pulses captured in the giant magnetic flare from a neutron star**  
22/12/2021  
In just a tenth of a second, a magnetar—a particularly strongly magnetized neutron star—released energy equivalent to that produced by the Sun in 100,000 years. Its detailed study revealed multiple pulses at the peak of the eruption, which will make it possible to understand these still little-known giant magnetic flares.

**The dramatic final dance of stars with shared envelope**  
16/12/2021  
The IAA-CSIC participated in the study of fifteen peculiar stars; they turned out to be double stars that, after sharing an envelope, lost a large part of their mass.

**Double helix structure observed in the jet emanating from the black hole in M87 galaxy**  
07/12/2021  
Produced by the magnetic field, it is the first time that this structure was observed at such far distances from the black hole. The IAA-CSIC participated in the discovery.
Giant planets could reach maturity sooner than expected
02/12/2021
The IAA-CSIC participated in the study of the giant planets of the V1298 Tau system, which in just twenty million years already reached their final size. The finding was possible thanks to radial velocity measurements from the HARPS-N spectrograph, at the Roque de los Muchachos Observatory (ORM), and from CARMENES, at the Calar Alto Observatory (CAHA).

The researcher Isabel Márquez and the Outreach Department at the IAA-CSIC, received “Granada Ciudad de la Ciencia y la Innovación” awards
01/12/2021
The aim of these awards is to recognise and disseminate the excellent scientific activity in the area of Granada.

On fire and in the process of breakind up by its star companion
25/11/2021
Found a system formed by a white dwarf star and a small object, possibly a planet, so close that the second is scorched by the star’s radiation, causing its atmosphere to evaporate.

Discovery of a possible satellite galaxy of M33, a neighbouring Local Group galaxy
17/11/2021
M33, also known as the Triangle galaxy, is the third largest galaxy in the Local Group, after Andromeda and the Milky Way. The finding was part of the search for the “lost satellites”, which tries to resolve the discrepancy between the galaxy formation models and the observations of the Local Group galaxies.

New perspectives on the problem of galaxies without dark matter
11/11/2021
The discovery of numerous very low surface brightness galaxies in the environment of NGC 1052 provided a crucial clue to the debate about the lack of dark matter in some galaxies of this group. The new data point to the existence of a group of galaxies closer than NGC 1052, to which these anomalous galaxies would belong, and the proximity would solve the problem.

Rocco Lico awarded with a 2021 EHT Early Career Award
23/10/2021
Rocco Lico’s outstanding contributions to the EHT was recognised in the second annual EHT Early Career and Outstanding PhD Awards for “his dedication and positive contribution to the EHTC’s management processes and strategy, recognising his unique talent for combining management activities and innovative science”.

Planetary system found similar to the future of the Solar System after the Sun’s death
13/10/2021
Scientists from the IAA-CSIC were involved in the discovery of a system formed by a white dwarf star and a planet similar to Jupiter. The discovery, published in Nature, showed that planets can survive the death of their star.

Light pollution increased by at least 49% in the last 25 years
27/09/2021
The study only included data from satellites, very limited for the detection of blue light (the most polluting), so that the real increase could amount to 270% globally. The investigation revealed the seriousness of a problem that, according to experts, would worsen if the draft Royal Decree for energy efficiency were approved favours the use of blue light.

Remnants of the historic supernova of 1181 suggested it originated from the merger of two stars
22/09/2021
Chinese and Japanese texts documented the appearance of a supernova in the year 1181, and in 2021 the remnant of that explosion was located.

The IAA participated in the development of ‘Uchuu’, the most accurate and complete simulation of the universe.
14/09/2021
An international team of researchers developed the most realistic simulation of the universe to date. The creation, named ‘Uchuu’ (which means universe in Japanese) was made possible thanks to ATERUI II, the most powerful supercomputer in the world, built by the National Astronomical Observatory of Japan (NAOJ) to facilitate the understanding of different astronomical phenomena from a theoretical point of view.

The most detailed images of galaxies were obtained thanks to LOFAR, a network of 70,000 antennas
27/08/2021
The IAA-CSIC headed one of the eleven articles that made up a special issue of the journal Astronomy & Astrophysics on the results of LOFAR. This paper shows the structure of the system Arp 299, which stands out for its high rate of supernova production.

New technique to detect, without contact, viruses on surfaces
10/08/2021
Based on the use of hyperspectral images and data processing with advanced statistics and artificial intelligence, it was successfully applied in two synthetic models of SARIS-CoV-2. The research, which continues in humans, was funded by the Carlos III Health Institute and made it possible to patent a technique capable of simultaneously analyzing numerous samples without the need for contact or reagents.

The Perseid meteor shower arrived
02/08/2021
The Perseids are produced by the impact in our atmosphere of fragments of the meteoroid cloud of Comet 109P/Swift-Tuttle, and are also recorded on the surface of the Moon. During the peak, around August 11, up to fifty per se are observed per hour could be observed in places away from light pollution.

Small force, big effect: how planets can affect the Sun
29/07/2021
The IAA-CSIC is involved in developing a theory that supports the hypothesis that planets affect the Sun’s magnetic activity. It shows how the small influence of the planets could set a rhythm in a system like the Sun that, if confirmed, would allow events such as solar storms to be predicted more accurately.

The massive star that barely shone upon death
24/07/2021
The IAA-CSIC participated in two articles that disseminated the discovery of the shortest gamma ray burst (GRB) produced by the death of a massive star ever detected.

The enigmatic assembly process of the Sombrero galaxy
21/07/2021
The Sombrero galaxy, a strange hybrid between a spiral and an elliptical galaxy, was observed in detail to look for clues about its formation process. Unless a large elliptical structure surrounding the galaxy, probably the result of a minor merger with another galaxy, was characterised, the origin of its shape remains unknown.

The Event Horizon Telescope (EHT) pinpointed the central black hole of the galaxy Centaurus A
19/07/2021
The EHT collaboration, in which the IAA-CSIC participates, showed in unique detail the heart of Centaurus A, from which gigantic jets of matter emerge.

MeerKAT discovered a group of galaxies hidden in a well-studied region
15/07/2021
Its abundance of neutral hydrogen suggests that it is a group of galaxies in the process of formation.
CARMENES instrument found two new planetary systems formed by Earths and super-Earths
30/04/2021
The IAA-CSIC led the detection of what, according to the data, is the most common type of planetary systems around dwarf stars, the most common stars in the Milky Way.

Noctilucent clouds observed from the Observatory of Sierra Nevada
24/05/2021
Noctilucent clouds were observed from the Sierra Nevada Observatory (OSN). The presence of this type of cloud is considered as an indicator of climate change and for years they have been observed at increasingly lower latitudes. This is one of the first times that they were observed from Granada.

CAIRT mission, with the participation of the IAA-CSIC, candidate for ESA’s Earth Explorer 11 programme
16/06/2021
The mission will focus on processes combining atmospheric circulation, composition, space weather and regional climate change, and will provide critical observations not available with existing or planned satellites.

IAA researchers published the most detailed star catalogue of the Galactic Centre
08/04/2021
The GALACTICNUCLEUS project makes it possible to study the stellar population surrounding the supermassive black hole at the Galactic Centre in unprecedented detail. The work, led by the IAA-CSIC, offered the most extensive census of stars in the Galactic Core recorded to date.

Juice mission prepared for its extreme environmental test
24/05/2021
JUICE, a European Space Agency (ESA) mission to be launched in September 2022, will study Jupiter and its moons to analyse the possibility for the development of life around gas giant planets. The IAA-CSIC participates in two of the mission’s instruments, the GALA laser altimeter and the JANUS camera.

Presentation of the project “Hello Earth”
30/04/2021
The IAA-CSIC welcomed the presentation of the project of the musician Antonino Arias based on the poems of the astronaut Al Worden. The project, which had the participation of the Cervantes Institute and the IAA-CSIC, includes an album, a book and a documentary.

A method to study distorted white dwarf stars was developed
26/04/2021
The IAA-CSIC led a study to determine the properties of stars that, either because of rapid rotation or because they are in a very compact double system subject to strong tidal forces, showed a flattened shape.

OPTICON-Radionet PILOT (ORP), the largest astronomy network in Europe, was born
16/04/2021
Two astronomy networks came together to form the largest collaborative ground-based astronomy network in Europe.

What ignites the helium halos of early galaxies remains a mystery
12/04/2021
A study led by IAA-CSIC targeted the galaxy IZw18, an analogue of the first galaxies that appeared in the universe, for understanding the origin of the radiation that produces a helium halo around it.

MAAT: new “eyes” for the OSIRIS instrument of the Gran Telescopio Canarias (GTC)
30/03/2021
MAAT, a visiting GTC instrument in the preliminary design phase, planned to bring the technique known as integral field spectroscopy to the OSIRIS instrument.

Astronomers imaged Magnetic Fields at the Edge of M87’s Black Hole
24/03/2021
The Event Horizon Telescope (EHT) reached a new milestone in astronomical observation by analyzing M87’s supermassive black hole in polarized light.

Observed for the first time a jet of gas as it emerges from the central star of a planetary nebula
10/03/2021
Thanks to MEGARA instrument of the Gran Telescopio Canarias, researchers from the IAA-CSIC observed and analyzed the jet of NGC 2392, which points to the existence of a companion star.

A Super-Earth well suited for atmospheric studies was found
04/03/2021
The IAA-CSIC participated in the discovery of a planet around the red dwarf star Gliese 486, a system placed at 26 light years from us.

Researcher Mirjana Povic received the Jocelyn Bell Burnell Award from the European Astronomical Society
02/03/2021
Researcher at the Ethiopian Institute of Science and Technology and a vinculated doctor to the IAA-CSIC, she investigates the formation and evolution of galaxies. She works in the development of science and education in Africa, with a special focus on the role of women, with projects in Ethiopia, Uganda, Rwanda, Tanzania, South Africa, Kenya and Ghana.

The Exoplanet Revolution
23/02/2021
Didier Queloz, 2019 Nobel Prize in Physics for the discovery of the first exoplanet around a star similar to the Sun, will give a seminar on the planetary systems found to date and their implications for our vision of the universe.

The IAA Advanced School of Planetary Systems, open to the public
15/02/2021
Organized within the framework of the IAA Severo Ochoa-IAA project, it addresses our knowledge of exoplanetary systems from a broad and updated context.

ExoMars mission discovered new gas and tracks water loss on Mars
10/02/2021
The ExoMars-TGO orbiter, from the European Space Agency and Roscosmos, found hydrogen chloride in the Martian atmosphere, produced by the release of salt embedded in the planet’s surface. The ExoMars data also allowed quantifying the loss of water on the red planet and establishing the mechanisms that contribute to the process.

The largest radioastronomy observatory in the world, SKAO, was born
04/02/2021
Spain is among the participating countries in the SKA Observatory (SKAO), an intergovernmental organization that will open a new era in radioastronomy. The Minister of Science, Pedro Duque, highlighted it as a milestone that will revolutionize astronomy and other scientific and technological fields. Spanish participation in SKA is led by the IAA-CSIC.

A “magnifying glass” looked at one of the largest known centaurs
03/02/2021
Thanks to a celestial occultation, a research led by IAA-CSIC was able to determine the characteristics of 2002 GZ32, a centaur with a diameter of almost 400 km on its major axis. Known for more than forty years, little information is available about this group of icy objects orbiting the Sun between the orbits of Jupiter and Neptune.

The IAA developed a study showing a decrease in light pollution in Granada during confinement
19/01/2021
Although similar studies were carried out in other countries, this is the only one that obtained results thanks to the combination of observations from satellite and from the ground.

A study of the radio emission of Proxima Centauri, the closest planetary system, opened a new path for the study of exoplanets
14/01/2021
Researchers from the IAA-CSIC led an ambitious radio observation project showing that extrasolar planets can be detected with radio telescopes.
List of publications


3. Amado, P. J.; Bauer, F. F.; López, C. Rodríguez; Rodríguez, E.; et al. The CARMENES search for exoplanets around M dwarfs: Two terrestrial planets orbiting G 264-012 and one terrestrial planet orbiting Gl 693, Astronomy & Astrophysics, 2021, 650, A198. DOI: 10.1051/0004-6361/20203803


INVITED

Dmitry Blinov  
Foundation for Research and Technology Hellas. Greece  
12/11/2021 - 14/12/2021  
31/10/2021 - 11/11/2021

Carolina Casadio  
University of Manchester. UK  
12/07/2021 - 20/08/2021

Arianna Cortesi  
Observatório do Valongo. Brasil  
08/11/2021 - 08/02/2022  
20/09/2021 - 07/11/2021

Ana Karla Díaz Rodríguez  
Istituto Nazionale di Fisica Nucleare. Italy  
01/12/2021 - 31/05/2022  
01/04/2021 - 30/06/2021

Joel Sánchez Bermúdez  
Universidad Nacional Autónoma de México. Mexico  
25/10/2018 - 15/12/2021

LONG VISITS

Vieri Bartolini  
Università di Bologna. Italy  
02/03/2021 - 02/07/2021

Valentin Boyanov Savov  
Universidad Complutense de Madrid. Spain  
04/08/2021 - 27/08/2021  
26/06/2021 - 21/07/2021  
12/04/2021 - 12/05/2021  
20/04/2021 - 31/03/2021

Michael James Francis  
University of Exeter. UK  
01/09/2021 - 31/08/2022

Gerardo García Moreno  
Universidad Complutense de Madrid. Spain  
20/12/2021 - 25/12/2021  
03/11/2021 - 19/11/2021  
18/10/2021 - 29/10/2021  
16/09/2021 - 15/10/2021  
10/05/2021 - 31/05/2021

Angela Gardini  
Universidad de Granada. Spain  
21/10/2019 - 31/08/2021

Valentin Michel  
ENSTA - Institut Polytechnique de Paris. France  
18/05/2021 - 06/08/2021

David Eduardo Millán Calero  
Universidad de Granada. Spain  
13/07/2018 - 13/07/2022

Sabela Reyero Serantes  
Univ. de Salamanca. Spain  
12/04/2021 - 20/07/2021

Flavia Rommel  
Observatorio Nacional de Rio de Janeiro. Brasil  
14/08/2021 - 31/12/2021

David Rosado Belza  
Instituto de Astrofísica de Canarias (IAC). Spain  
18/11/2021 - 28/04/2022

Tianrui Sun  
University of Shanghai. China  
05/04/2021 - 04/04/2022

Shimeles Terefe Mengistue  
Ethiopian Space Science and Technology Institute. Ethiopia  
28/06/2021 - 25/12/2021

SHORT VISITS

Roldán Alonso Cala Barón  
Universidad de Granada. Spain  
18/05/2021 - 18/05/2021

Miguel Cano González  
Universidad de Oviedo. Spain  
07/12/2021 - 15/01/2022

Alejandro Manuel Cardesin Moinelo  
ESAC. Spain  
06/09/2021 - 24/09/2021  
02/11/2021 - 02/12/2021

Aline Chu  
Institut d’Astrophysique de Paris. France  
14/10/2021 - 24/10/2021

Miriam Cisneros  
Royal Belgian Institute for Space Aeronomy. Belgium  
13/10/2021 - 21/10/2021

Gabriela Columba  
Università di Padova. Italy  
05/11/2021 - 24/11/2021

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25/12/2020 - 10/11/2021

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24/05/2021 - 28/05/2021

Chi An Dong Paez  
University of Cambridge. UK  
08/07/2021 - 30/07/2021

Ruben Fedriani  
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13/12/2021 - 17/12/2021

Gabriella Gilli  
Instituto de Astrofísica e Ciências do Espaço. Portugal  
27/05/2021 - 31/05/2021

Lorena Hernández García  
Universidad de Valparaíso. Chile  
05/09/2021 - 10/09/2021

Kelley Michelle Hess  
ASTRON. Netherlands  
04/10/2021 - 11/10/2021

Steffen Hess  
ASTRON. Netherlands  
11/07/2021 - 17/07/2021

Ángel Luis Huelmo Iglesias  
Central nuclear de Almaraz. Spain  
06/03/2021 - 14/03/2021

Luca Izzo  
Dark Cosmology Centre – Univ. of Copenhagen. Denmark  
28/06/2021 - 01/07/2021

Santiago Jiménez Corral  
Universitat de València. Spain  
21/05/2021 - 21/05/2021

Guillermo Manjarrez Esquivel  
Universidad de Granada. Spain  
04/06/2021 - 04/06/2021

Paola Marziani  
INAF. Italy  
31/10/2021 - 15/11/2021

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04/06/2021 - 04/06/2021

Francisco Nogueras Lara  
Max Planck Institute for Astronomy  
08/11/2021 - 13/11/2021

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01/12/2021 - 03/12/2021

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28/06/2021 - 03/07/2021

Conrad Schwanitz  
ETH Zurich. Switzerland  
04/10/2021 - 08/10/2021

Efthalia Traianou  
Max Planck Institute for Radioastronomy. Germany  
13/12/2021 - 21/12/2021
In memoriam

José María Jerónimo, Chema in the IAA and Pepe for his family, has been and is an inseparable part of the IAA since his incorporation in 1981. His knowledge in electronics and his good manners of working have been collected in successive space exploration projects among which it is worth mentioning from the development of rocket payloads for the study of the upper atmosphere to his participation in NOMAD-Exomars, through HASI in Huygens and in GIADA, on board Rosetta, and the PLATO mission.

The results of his work are physically present on Earth, Titan, the surface of comet Churyumov-Gerasimenko and on two spacecraft orbiting Mars, but above all they are and will continue to be among those of us who have had the good fortune to have known him and shared a multitude of experiences over these almost 40 years.

Who can offer so much?

José Juan López Moreno
Ad Honorem Professor (IAA-CSIC)