ia

instituto de astrofísica
e ciências do espaço

Institute of Astrophysics and Space Sciences

2021 Activity Report

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e ciências do espaço

Ciências ULisboa
U.PORTO
1290 UNIVERSIDADE D COIMBRA

COFINANCIAMENTO / COFINANCING
FCT Fundação para a Ciência e a Tecnologia
COMPETE 2020
PORTUGAL 2020
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

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Unit Overview

The **Instituto de Astrofísica e Ciências do Espaço (IA)** is a research infrastructure with a national dimension, embodying a bold vision for the development of Astronomy, Astrophysics and Space Sciences in Portugal. It is the largest research unit of this area in the country, being responsible for the majority of the national productivity in international ISI journals in the area of Space Sciences — one of the scientific areas with the highest relative impact factor and highest average number of citations per article for Portugal. IA has a demonstrated ability to drive major astronomical projects, at all development levels: scientific and technical definition, instrument concept and design, construction and commissioning, and scientific exploitation.

IA's mission is to foster research with the highest impact in the field of astrophysics and space sciences and to support teaching and training of young researchers and students in close collaboration with the Universities of Lisbon and Porto, and from June 2021, in Coimbra. Indeed, IA has now grown with the creation of a new pole at the University of Coimbra, with headquarters at the Observatório Geofísico e Astronómico of the University of Coimbra (OGAUC), of the Science and Technology Faculty of the University of Coimbra (FCTUC), which reveals the national impact of the IA. It also aims to promote wide-ranging science communication activities that enhance public understanding of the Universe and our place in it, as well as awareness of the importance of research in this field.

Our vision is to achieve international leadership in key areas of astrophysics and space sciences, taking full advantage and realising the potential created by the national membership of the European Space Agency (ESA) and the European Southern Observatory (ESO) and the Square Kilometre Array Observatory (SKAO). This is done through state-of-the-art research, enabled by our leading participation in strategic international ground and space-based projects and missions.

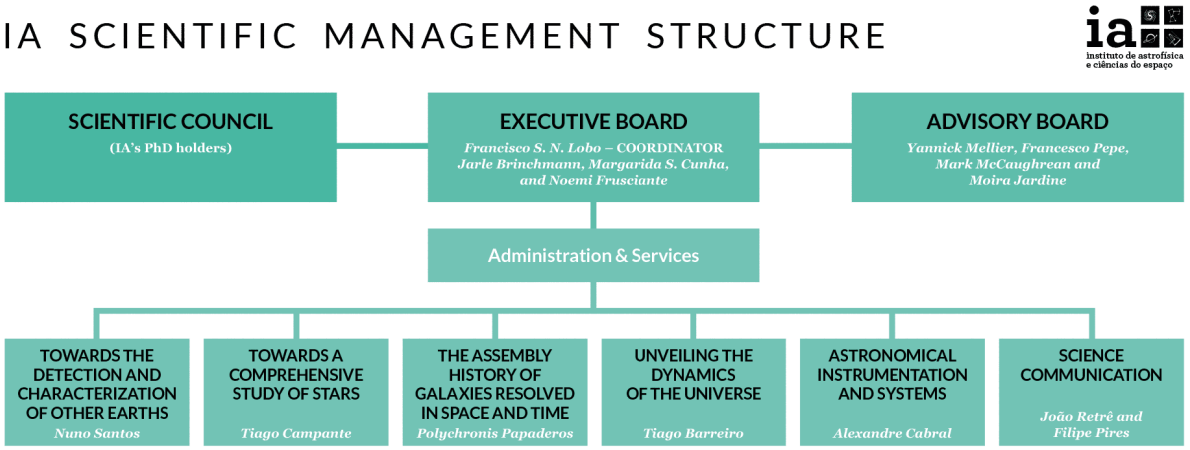
As in the previous year, 2021 was marked by the continued covid-19 pandemic which deeply influenced the activity of IA. The majority of the national and international projects suffered considerable delays, which also means IA activity didn't progress as otherwise planned. However, it was possible to keep the IA teams supported during this period, trying to help minimising the personal and professional impacts of covid-19. We should note that the IA team continued to produce high-impact scientific results, as clearly seen in our annual report below — probably even increasing the scientific productivity as many other preparatory activities (for scientific instruments, for example) were delayed. Considering the long-term effects of this pandemic year to the overall strategy of the Institute, it is our belief that throughout the rest of the funding period (2020-2023) the dynamic activity of IA will continue and there is no reason, at this point, to change the IA scientific strategy and workplan for the coming years.

As usual, you will find in the following pages an overview of IA's activities during 2021. Take a moment to also read between the lines and appreciate the personal efforts from researchers, students and support personnel that kept IA going during this year. We certainly do, and pay our homage to our team for their resilience in the face of specially hard, and hopefully soon-to-be-over, conditions.

Francisco S.N. Lobo, Jarle Brinchmann, Margarida S. Cunha, Noemi Frusciante
IA Executive Board

IA Management

The Executive Board (EB, elected in June 2021) is composed of 2 members from the Porto node (Jarle Brinchmann and Margarida S. Cunha) and 2 members from the Lisbon node (Francisco S.N. Lobo and Noemi Frusciante), with Francisco S.N. Lobo as the coordinator of the research unit.



During 2021, the EB continued having regular weekly meetings to coordinate the scientific and management activities of the IA strategic plan. Every other week these meetings also include group leaders, including the Science Communication Group. Contacts with the two management institutions (CAUP and FCiências.ID) were also done whenever necessary.

IA-ON 8

Due to the pandemic restrictions the 8th Internal workshop (IA-ON 8) took place virtually from the 10th to the 11th of November and in person on the 12th of November.

The IA-ON 8 assembled most of the team, with an attendance of 125 participants among researchers, students, and support personnel. The highlights of the year were shared and discussed with the whole team, with many presentations being given by younger researchers who joined the team during 2021. In 2021, the focus was given to scientific discussions and strategy but not limited to them, IA-ON 8 also included sessions to discuss internal IA procedures and Gender, Equality, Diversity issues. During the last day of the workshop, the team met in person at the University of Coimbra, where the focus was on the presentation to the whole team of the scientific activities carried on by the IA members of the Coimbra node. Indeed the IA-ON 8 was the first internal workshop which saw the participation of the researchers of this node. After more than one year of pandemic and isolation this day also served to renew human contact among the team.

The IA team (2021)

Towards the detection and characterization of other Earths (Planets Group)

Researchers (PhDs)

- Alberto Negrão
- Elisa Delgado-Mena*
- Gabriella Gilli (left 31 may)
- Hugo M. Tabernero Guzmán (left 31 january)
- João N. T. Gomes da Silva
- João P. S. Faria
- Jorge H. C. Martins
- Nuno Peixinho * (joined 1 april)
- Nuno C. Santos
- Olivier Demangeon
- Pedro Figueira
- Pedro Machado
- Pedro Pina * (joined 1 june)
- Pedro T. P. Viana
- Sérgio A. G. Sousa *
- Susana C. C. Barros

Others

- Abderahmane Soubkiou (PhD student) (started 20 september)
- Alexandros Antoniadis Karnavas * (PhD student)
- Ana Barboza (left 30 september)
- Ana Rita Silva (PhD student) (started 1 october)
- André Miguel A. C. V. Silva * (PhD student)
- Babatunde Akinsanmi (PhD student) (finished 2 december)
- Bárbara M. T. B. Soares (MSc student, finished 30 september – PhD student, started 1 october)
- Constança T. Freire (MSc student) (started 30 september)
- Daniela C. Espadinha (PhD student)
- Diogo Quirino (MSc student)
- Eduardo Cristo (PhD student)
- Francisco Brasil (PhD student) (started 20 may)
- João André B. Dias (MSc student) (finished 31 december)
- João D. R. Camacho (PhD student)
- José Eduardo Oliveira Silva (PhD student)
- José Luís F. Ribeiro (PhD student)
- José Rodrigues (PhD student)
- L. Filipe Pereira * (PhD student) (finished 17 december)
- Mariana I. C. Reis (MSc student)
- Nuno A. R. Carvalho (MSc student)
- Nuno M. Rosário (PhD student)
- Paul Charpentier (internship) (14 june to 27 august)
- Ruben Gonçalves (PhD student)
- Saeed Hojjatpanah (PhD student) (finished 16 december)
- Sandie Marion (internship) (14 june to 27 august)

Towards a comprehensive study of stars (Stars Group)

Researchers (PhDs)

- Ângela R. G. Santos (joined 1 november)
- Anna Morozova (joined 1 april)
- Charlotte Gehan (left 30 april)
- Daniel F. M. Folha
- Diego Bossini
- Elisa Delgado Mena *
- João J. G. Lima
- João Lin Yun
- Jorge Filipe S. Gameiro
- Mário J. P. F. G. Monteiro
- M. S. Nanda Kumar
- Margarida S. Cunha
- Maria Teresa Barata (joined 1 april)
- Maria Teresa V. T. Lago
- Morgan Deal
- Nuno Peixinho * (joined 1 april)
- Pedro Pina * (joined 1 june)
- Pedro M. Palmeirim
- Pedro Pina Avelino *
- Ricardo Jorge Gafeira (joined 1 april)

Others

- Alexandros Antoniadis Karnavas * (PhD student)
- Andreas W. Neitzel (joined 1 september)
- Ayoub Ait Benhamou (internship) (15 march to 16 august)
- Eva L. Silva (MSc student) (started 1 november)
- Hernán Cerviño Asorey (MSc student) (finished 10 december)
- L. Filipe Pereira * (PhD student) (finished 17 december)
- Margarida Santiago (MSc student) (started 1 november)
- Miguel Clara (PhD student)
- Nuno Moedas (PhD student)
- Paulina M. Zaworska (PhD student)
- Pedro M. Martins
- Slava L. L. Bourgeois (PhD student) (started 1 october)
- Thibault Boulet (PhD Student)

The assembly history of galaxies resolved in space and time (Galaxies Group)

Researchers (PhDs)

- Ana S. Paulino Afonso (joined 1 november)
- Andrew J. Humphrey
- Catarina Lobo
- Cirino Pappalardo
- Iris P. Breda (left 14 january)
- Israel Matute
- Jarle Brinchmann
- Jean Michel Gomes
- José Afonso
- Patricio Lagos
- Polychronis Papaderos
- Rui Agostinho *

Others

- Abhishek Chougule (PhD Student)
- André Pinheiro (MSc student) (started 15 october)
- Cristina Meng (PEEC) (8 february to 29 july)
- Daniel A. D. Vaz (MSc student, finished 19 october – PhDstudent, started 20 october)
- Davi D. Barbosa (PhD student)
- Duarte M. Santos (MSc student) (started 1 september)
- Henrique Miranda (MSc student) (finished 16 december)
- Mariana P. Júlio (MSc student) (finished 26 november)
- Pedro Alexandre C. Cunha (MSc student, finished 30 september – PhD student, started 1 october)
- Rodrigo A. Carvajal Pizarro (PhD student)
- Sandra N. Reis (PhD student) (finished 30 april)

Stergios Amarantidis (finished PhD 27 may)

Tom C. Scott

Sandy G. Morais (PhD student)

Unveiling the dynamics of the Universe (Cosmology Group)

Researchers (PhDs)

Alberto Rozas-Fernández

Andrew R. Liddle

António C. da Silva

Carlos J. A. P. Martins

Claudio Llinares

Francisco S. N. Lobo

Francisco T. O. Cabral (15 july to 24 november)

Giuseppe Fanizza

Ismael Tereno

Ivan Rybak

José Carlos Fonseca (joined 1 september)

José Pedro Mimoso

Lara G. Sousa

Marina Cortês

Nelson J. Nunes

Noemi Frusciante

Paulo Crawford

Paulo M. Sá (joined 17 december)

Paulo Maurício de Carvalho

Pedro Pina Avelino *

Others

Ana C. O. Leite (PhD student)

Ana P. Rodrigues (MSc student) (finished 20 july)

Ana Rita R. Almeida (MSc student) (finished 2 december)

Ana Sofia Carvalho (PhD student)

Axel Lapel (internship) (8 march to 20 august)

Bruno André R. Rocha (MSc student) (finished 25 november)

Bruno J. Barros (PhD student) (finished 11 may)

David Grüber (PhD student)

Diogo A. R. Pinheiro (PEEC) (1 february to 30 september)

Diogo M. L. Castelão (PhD student)

Filipe A. A. Costa (PEEC) (1 february to 30 september)

Filipe Correia (MSc student) (started 1 october)

Francisco C. N. Q. Pimenta (PEEC, 1 february to 30 september - MSc student, started 1 october)

Francisco P.S. A. Ferreira (PEEC) (1 february to 30 september)

Francisco T. O. Cabral (PhD student) (finished 15 july)

Hilberto M. R. da Silva (MSc student, finished 30 september – PhD student, started 1 october)

Inês Albuquerque (PhD student)

Ismael Ayuso (PhD student)

João D. F. Dias (PhD student) (joined 4 january)

José Ferreira (MSc student) (started 1 october)

José Ricardo Correia (PhD student)

Julien Poyatos (internship) (15 february to 13 august)

Júlio S. J. S. Oliveira (PEEC) (1 february to 30 september)

Luís Atayde (MSc student)

Mafalda Castro S. X. Matos (PEEC) (finished 30 september)

Maria Alexandra Gonçalves (MSc student) (started 1 september)

Miguel J. P. C. Conceição (PhD student) (joined 1 october)

Miguel Pinto (MSc student) (started 1 october)

Pedro V. Marto (PEEC) (1 february to 30 september)

Renata S. Trintin (PhD student) (joined 1 september)

Rui P. L. Azevedo (PhD Student)

Sara N. F. de Nóbrega (joined 18 june)

Sergei Mukovnikov (PhD student, started 1 october)

Thomas Raveau (internship) (22 february to 20 august)

Tiago Barreira Gonçalves (PhD student) (joined 24 march)

Vasco M. C. Ferreira (PhD student) (finished 16 december)

Vítor da Fonseca (PhD student) (joined 10 may)

Astronomical Instrumentation and Systems (Instrumentation Group)

Researchers (PhDs)

Alexandre Cabral

Bachar Wehbe (finished PhD student 2 june)

Elena Duarte

João Coelho

João Dinis

José M. Rebordão

Manuel Abreu

Raúl Cerveira Lima (joined 7 april)

Sérgio A. G. Sousa *

Alexandre Cabral

Bachar Wehbe (finished PhD student 2 june)

Elena Duarte

João Coelho

João Dinis

Others

Andreia Domingos (MSc student)

André Miguel A. C. V. Silva * (PhD student)

António Oliveira

Bachar Wehbe (PhD student) (finished 2 june)

Cédric P. Pereira (PhD student)

Francisco Guerreiro (MSc student)

Guilherme Roque (MSc student)

Inês Machado (MSc student) (started 1 september)

Inês Leite (MSc student, finished 30 september - PhD student, started 1 october)

João Cachatra (MSc student)

Manuel Monteiro

Science Communication Group

Catarina Leote

Elsa M. P. S. Moreira

Filipe A. L. Pires

Hilberto M. R. Silva (left 18 march)

Ilídio André P. M. Costa

José Manuel C. Dantas

João Retrê

Paulo J. T. Pereira

Ricardo S. S. C. Reis

Sérgio Pereira

Tânia F. S. Cunha

Catarina Leote

Interface to Science (Support to Science Activities)

Argentina Pereira

Carlos Santos

Elsa Marta Silva

Marlene Cruz (left 31 october)

Sandra Homem

Researchers that work in more than one group are marked with (*).

Research Projects/Programmes

During 2021, a number of funded projects were on-going at IA, providing most of the funds available for research, including outreach activities.

Projects focused on scientific activities

The research projects that in 2021 were supported by national and European funds are:

(i) **Projects funded by the European Commission (EC):**

- SKilled, Innovative & Entrepreneurial Scientists (SKIES) (GA Nº 101006212)
  PI: Jarle Brinchmann
  [start date: 01 March 2021 – end date: 31 August 2022]

- Revealing the Milky Way with Gaia (MW-GAIA) (COST ACTION CA18104)
  PI: Vardan Adibekyan & Nuno Santos
  [start date: 14 March 2019 – end date: 13 March 2023]

(ii) **Research projects funded by Fundação para a Ciência e a Tecnologia (FCT):**

- Characterizing the smallest planet hosts (IF/00849/2015/CP1276/CT0003)
  PI: Elisa Delgado Mena
  [start date: 1 January 2017 – end date: 31 March 2022]

- Zoom-In ON hIgh-mass Star forMation (ZIONISM) (IF/00956/2015/CP1273/CT0002)
  PI: Nanda Kumar
  [start date: 15 December 2016 – end date: 14 March 2022]

- Probing the Physics of the Dark Universe with Euclid (IF/01135/2015)
  PI: António da Silva
  [start date: 3 October 2016 – end date: 2 January 2022]

- Modified Gravity impact on Cosmology and Astroparticles (MGiCAP)
  (CERN/FIS-PAR/0037/2019)
  PI: Francisco Lobo
  [start date: 1 September 2020 – end date: 31 August 2022]

- Probing cosmic strings and other topological defects with gravitational waves (Gwstrings)
  (POCI-01-0145-FEDER-031938 & PTDC/FIS-PAR/31938/2017)
  PI: Lara Sousa
  [start date: 15 October 2018 – end date: 14 October 2022]

- Planets – Towards Understanding their General circulation Atmospheres (P-TUGA)
  (PTDC/FIS-AST/29942/2017)
  PI: Pedro Machado
  [start date: 3 September 2018 – end date: 2 June 2022]

- Identify the Earliest Supermassive Black Holes with ALMA (IdEaS with ALMA)
  (PTDC/FIS-AST/29245)
  PI: José Afonso
  [start date: 3 September 2018 – end date: 2 September 2022]

- Spacetime ripples in the dark gravitational Universe (DarkRipple)
  (PTDC/FIS-OUT/29048/2017)
  PI: Francisco Lobo
  [start date: 1 September 2018 – end date: 31 August 2022]

- a Generation of Earth-ANalogs Exploration Spectrographs (G.EANES)
  (POCI-01-0145-FEDER-032113 & PTDC/FIS-AST/32113/2017
  PI: Nuno Santos
  [start date: 1 August 2018 – end date: 31 July 2022]

- Cosmology and Fundamental Physics with ESPRESSO (CosmoESPRESSO)
  (POCI-01-0145-FEDER-028987 & PTDC/FIS-AST/28987/2017
  PI: Carlos Martins
  [start date: 1 June 2018 – end date: 31 May 2022]

- Exploring exoPlanets wIth CHEOPS (EPIC)
  (POCI-01-0145-FEDER-028953 & PTDC/FIS-AST/28953/2017)
  PI: Sérgio Sousa
  [start date: 1 June 2018 – end date: 31 May 2022]

- Breaking through outstanding problems in stellar evolution with ultra-precise space-based photometry (BreakStarS) (POCI-01-0145-FEDER-030389 & PTDC/FIS-AST/30389/2017)
  PI: Margarida Cunha
  [start date: 1 May 2018 – end date: 30 April 2022]

  Dark matter and metals in galaxies (DarkMAGE) (PTDC/FIS-AST/4862/2020)
  PI: Jarle Brinchmann
  [start date: 1 September 2021 – end date: 31 August 2024]

(iii) Infrastructure funded projects (FCT):

- R&D Unit 2020-2023 Financing: Instituto de Astrofísica e Ciências do Espaço (UIDB/04434/2020 & (UIDP/04434/2020)
  PI: Francisco Lobo
  [start date: 1 January 2020 – end date: 31 December 2023]

(iv) Cooperation projects funded by Gabinete de Relações Internacionais da Ciência e do Ensino Superior (FCT) and by Conselho de Reitores das Universidades Portuguesas

- Strategic partnership in astrophysics Portugal-Brazil: the connection between black holes and galaxies using powerful new instrumentation and theoretical insights (Cooperação Científica e Tecnológica FCT/CAPES)
  PI: Andrew Humphrey
  [start date: 1 May 2018 – end date: 31 December 2022]

- Evolution of realistic cosmic strings and superstrings (Convénio FCT/CNRS)
  PI: Carlos Martins
  [start date: 1 July 2021 – end date: 30 June 2023]

(vi) Other projects

- Participation to CHEOPS Science Operations Centre (SOC)
  PI: Nuno Santos
  [start date: 31 October 2013 – end date: 31 October 2023]

- PLATO OGSE and PDC Phase B (ESA Contract No. 4000133026)
  PI: Nuno Santos
  [start date: 1 January 2018 – end date: 31 December 2022]

- On-board Metrology for Athena (ESA Contract No. 4000131014/20/NL/HB/gg)
  PI: Manuel Abreu
  [start date: 19 June 2020 – end date: 1 October 2022]

Projects focused on communication and outreach

During 2021 there were several funded projects in IA:

- AstroCamp 2021
  PI: Carlos Martins
  [start date: 1 january 2021 – end date: 1 December 2021]

- Ciência Viva no Verão em Rede 2021
  PI: Filipe Pires
  [start date: 1 July 2021 – end date: 30 September 2021]

- Formação ESERO
  PI: Filipe Pires/Ilídio Costa
  [start date: 1 January 2021 – end date: 31 December 2021]

- Renewing the solar system exhibition – Europlanet Society
  PI: João Retré
  [start date: 1 January 2020 – end date: 31 December 2022]

- Light Fingerprints - Europlanet Society
  PI: Nuno Santos
  [start date: 1 january 2021 – end date: 31 December 2022]

- SDSS block grants for Plate distribution
  PI: Filipe Pires/Ilídio Costa
  [start date: 1 january 2021 – end date: 31 December 2022]

- Capacitação dos Centros de Ciência Viva (NORTE-09-5864-FSE-000027)
  PI: Filipe Pires
  [start date: 1 April 2021 – end date: 31 March 2023]

Scientific Output and Activities

The overall output of IA in **2021** was (see Appendix for details)

211
Papers in refereed journals

6
Papers in books and proceedings

139
Communications in international meetings

75
Communications in national meetings

26
Seminars in other institutions

22
Seminars organized at IA

148
Public outreach talks

10
MSc thesis completed

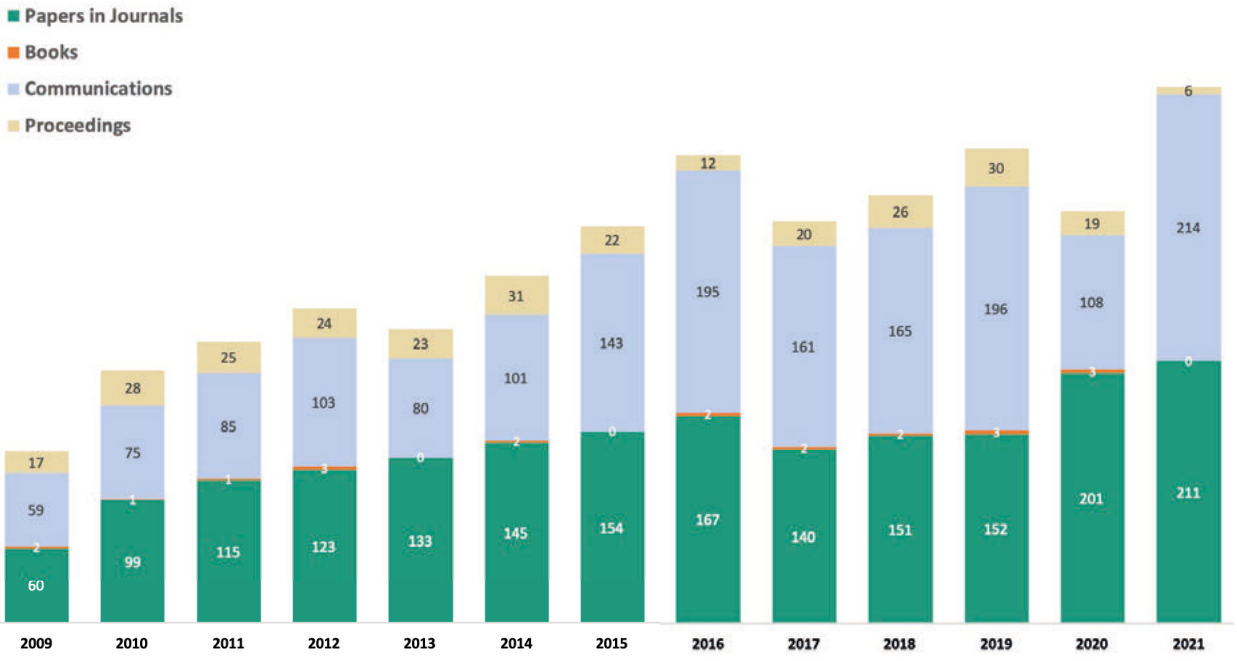
10
PhD thesis completed

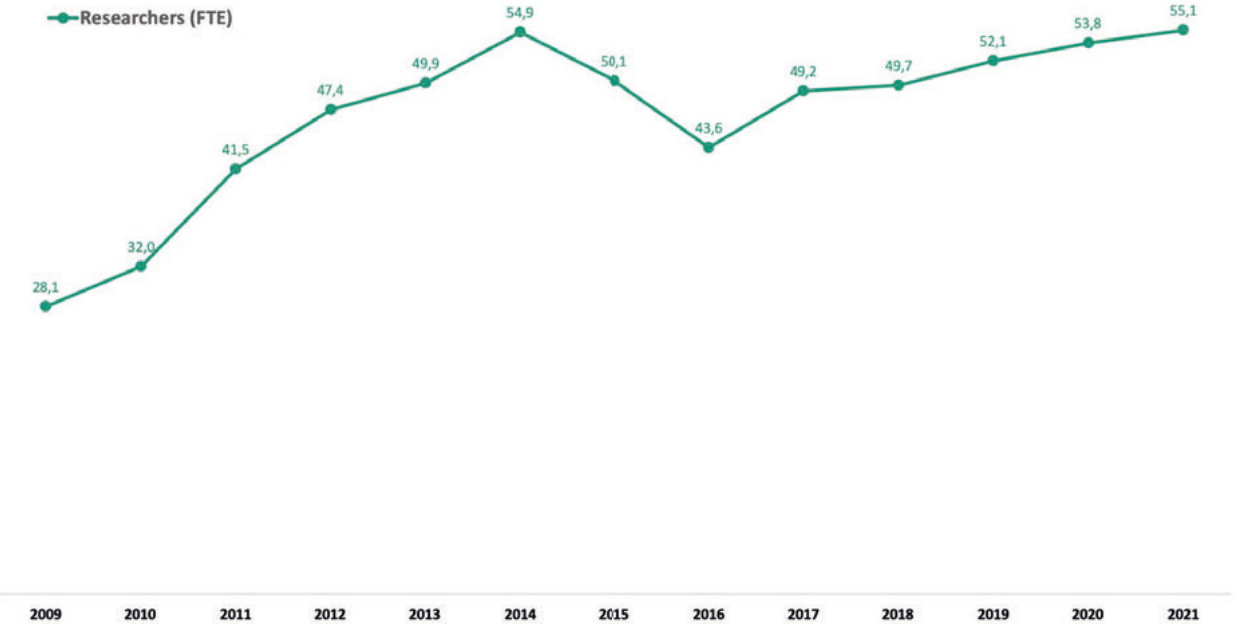
28
Observing runs

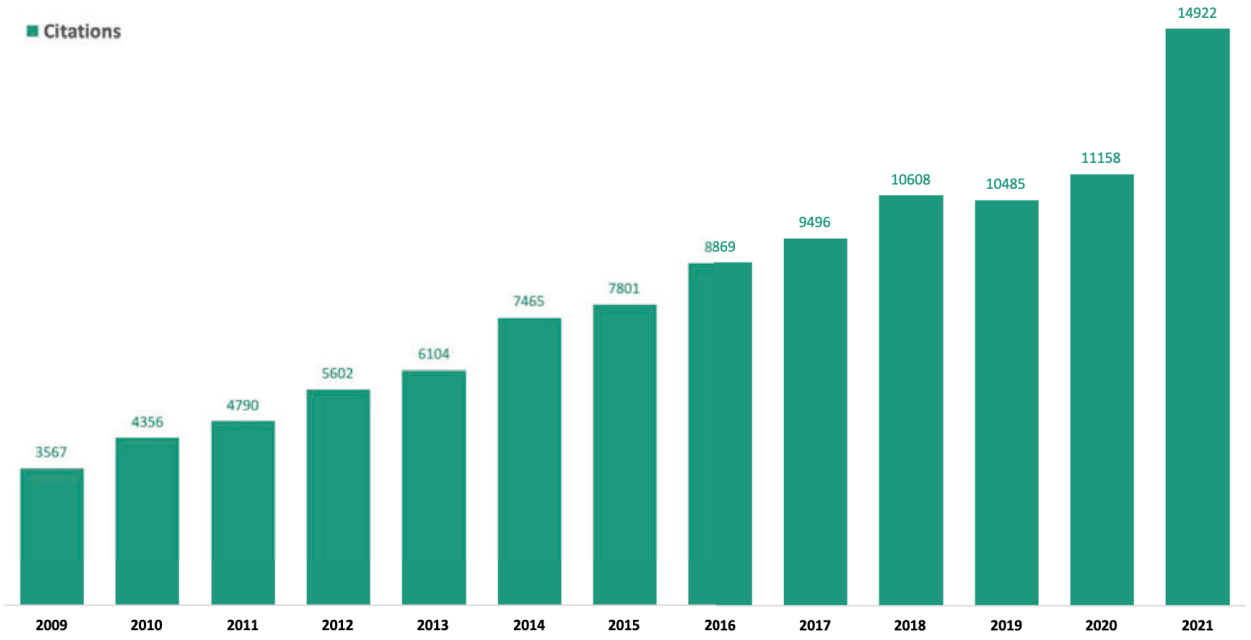
11
Organization of conferences

6
Reports

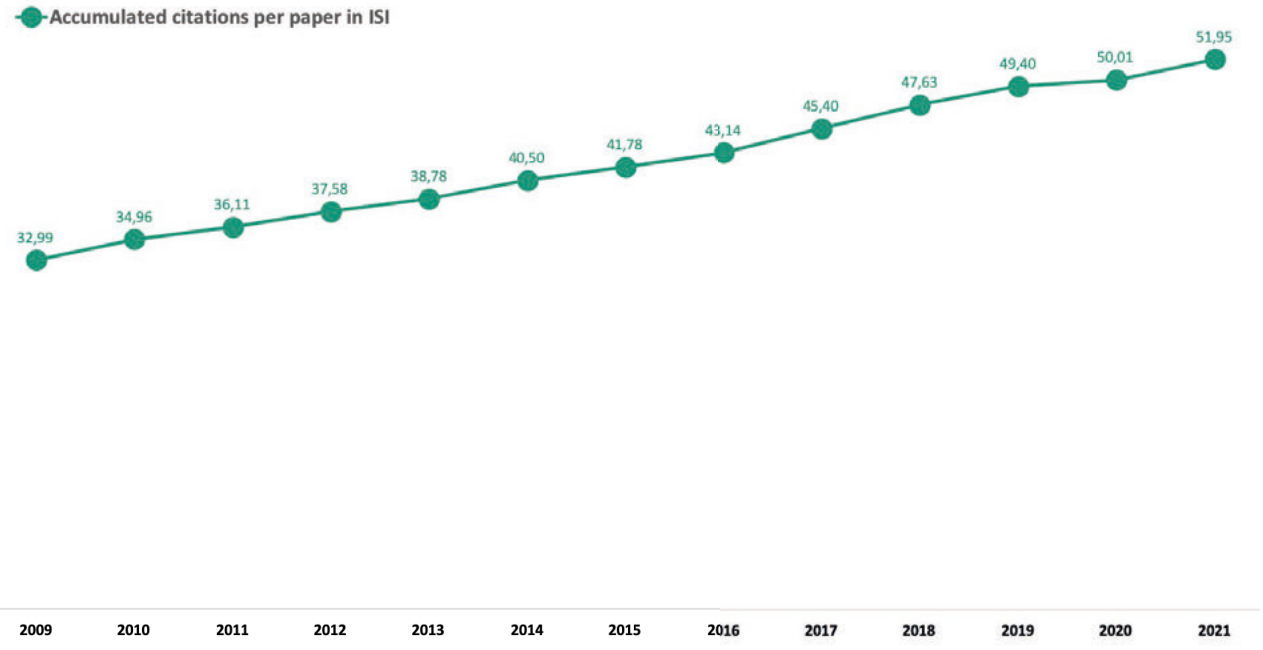
The figures below illustrate the institute's productivity during the past year. There is a clear and natural relation between the number of researchers and the number of papers in journals subject, understandably, to a small shift in time. The figures show a continuation of the increase in the number of publications and communications, which is a strong indication for the strong activity of the Institute. The number of citations also maintains an increasing trend which is not simply justified by an increase in the numbers or articles. Indeed, the figures show that the accumulated impact continues to grow.







The number of citations obtained in a given year for all the IA articles published since 1990 up to that year.



The accumulated impact in a given year is measured as the ratio between the sum of the number of citations up to that year since 1990 and the number of articles in the same period.

Report from the Group

Towards the detection and characterisation of other Earths

The Planetary System team at IA continued its activities around the two major branches, namely Exoplanet research and Solar System atmospheres. Additionally, with the inclusion of colleagues from the new Coimbra node, the activities also expanded to the study of minor bodies in the Solar System and the study of planetary surfaces.

Exoplanet research focused on multiple complementary aspects: 1) the search and characterization of exoplanets using state-of-the-art radial velocity data, including the detection and mass measurement of planets previously detected by the transit method (e.g. with missions such as TESS); 2) the study of astrophysical sources of noise for the detection and characterization of planets as well as methods to correct/model them; 3) the study of planet-host stars as a way to characterise planets as well as their properties and formation processes; 4) the statistical study of planet properties as well as the relation with the properties of the host stars; 5) the study of exoplanet atmospheres using broad-band photometry, high-resolution spectroscopy and model atmospheres.

A significant part of this research was done in the context of our top-level participation as consortium members in ESO's ESPRESSO project (started operations in 2018) and ESA's CHEOPS mission (launched in late 2019). Given our key roles and contributions in the project phase, we have been exploiting our privileged access to the definition of the science programs of ESPRESSO and CHEOPS, as well as the analysis of the obtained data. Several high impact results were published based on these data, and several others are in preparation. Data from the SPIROU@CFHT consortium has also been explored. Furthermore, making use of the know-how that was (and is) built from these projects, we are now preparing for the new NIRPS@ ESO's 3.6m, which is expected to see first light in Summer 2022.

Our high level participation in these projects reinforces the existing strategy and allows the team to be in the forefront of exoplanet detection and characterization. In this context, we are already preparing for future projects and missions such as the HIRES@ESO's ELT spectrograph (2030, approved for construction by ESO in December 2021) as well as the PLATO and ARIEL missions (ESA - 2026 and 2029, respectively). For all of those, we are responsible for scientific tasks as well as part of the data reduction/analysis pipelines.

On the Solar System side, research mainly focused on solar-system planet atmospheres, with clear synergies with the exoplanet side. However, as mentioned above, the inclusion of members from the new Coimbra node of IA allowed to broaden the expertise of the team to areas such as the study of Solar System minor bodies and planetary surfaces.

Within this context, in 2021 the team continued different studies of the atmospheres of Venus, Mars, Saturn, and Jupiter. We can highlight here the use of both ground and space-based observations to perform dynamical studies based on cloud tracking techniques (UV and IR) and the detection and characterization of atmospheric waves. The development of atmospheric models (using state-of-the-art Global Circulation Models) of Solar System bodies has also been pursued.

Scientific Highlights for 2021

In 2021, a total of 8 IA Press-releases were published announcing scientific or science-related results with a leading or major participation of the team. Most of them were done in an international context. The list of highlights below is based on some of these.

Discovery of an exoplanet with only half the mass of Venus

A research led by the IA (Demangeon et al. 2021) used the ESPRESSO spectrograph to detect a planet with only 1/2 the mass of Venus. In a system with 5 planets, it is the lowest mass planet with a mass measured using the radial-velocity method.
Three exoplanets, similar to the inner planets of the Solar System, were revealed around the star L98-59 by NASA's TESS mission. TESS, however, is not able to measure the masses of the planets, and only their radii (through transit photometry) are measured. Knowing the mass and the radius is however key to understanding the planet composition, and distinguishing between rocky planets and their ice and gas giant counterparts.
To tackle this issue, over the last two years the IA team obtained ESPRESSO data on the system (as part of our strong participation in the ESPRESSO consortium). A detailed analysis of the data allowed us to show that one of these planets (the one orbiting closer to its star) has about half the mass of Venus. This is the exoplanet with the lowest mass measured with the radial velocity method, being even smaller than the Earth. This measurement was only possible due to the many years of improvements in instruments and data analysis techniques, to which IA members made important contributions.

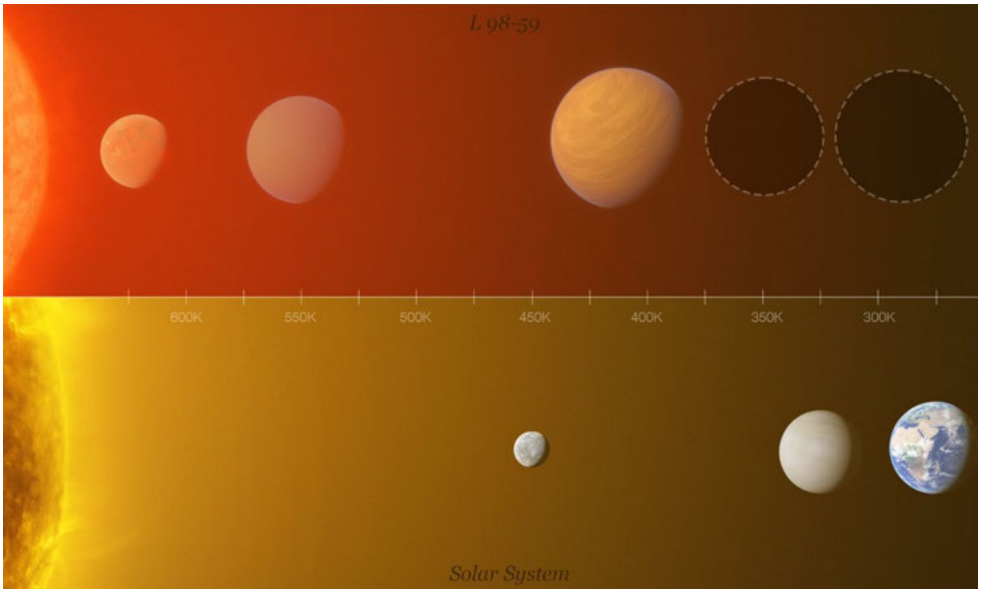


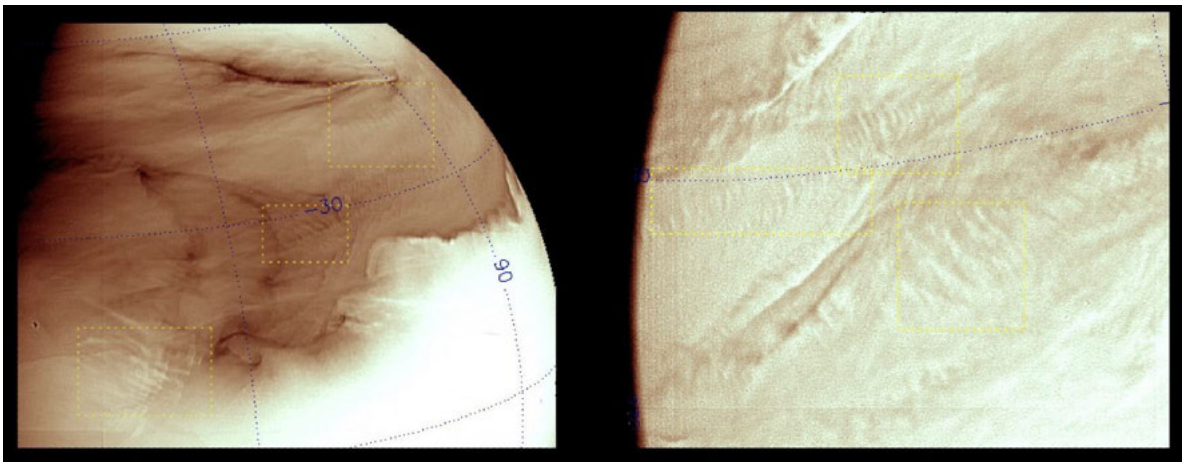
Figure: The L98-59 system when compared with our own Solar System rocky planets. Courtesy ESO.

Further to this amazing discovery, the team was also able to infer that three of the planets may contain water either inside or in their atmosphere. The two planets closest to the star are likely to be dry, but they may still contain small amounts of water. The third planet could have up to 30% of its mass in water, thus appearing to be an ocean world.

In addition, the team also discovered that L98-59 has additional exoplanets that until now had not been detected. A fourth planet has been discovered and a fifth is suspected to be in the habitability zone, the zone at the right distance from the star for a planet to have liquid water on its surface. These results (announced in an ESO Press Release) are an important step forward in the search for life on Earth-sized planets outside the Solar System. The detection of signs of the presence of life, the so-called biosignatures, on an exoplanet depends heavily on the ability of astronomers to study its atmosphere. However, current telescopes are not yet large enough to reach the resolution required to carry out this type of study on small rocky planets. The planetary system L98-59, just 35 light-years away from Earth, is therefore a good target for future observations of exoplanet atmospheres (e.g. with the HIRES@ELT spectrograph, a project on which the IA team is strongly involved).

Understanding the atmosphere of Venus

The largest-ever search for atmospheric wave patterns on the night side of Venus, and a new window on vertical winds, are the two important recent contributions to understanding the super-rotation of the cloud level on this planet, made by researchers at IA.
On a slowly rotating planet like Venus, but with constant winds beyond the most devastating hurricanes on Earth, any slight breeze could be part of the key to the mysterious “super-rotation” of its atmosphere. Now, two studies led by researchers from IA contribute to the ongoing effort to finally understand what makes the aerial envelope of Venus rotate so quickly.
A first study (Silva et al. 2021), published in the scientific journal Astronomy & Astrophysics, looked for wave patterns in low clouds, at about 47 kilometres altitude, in more than 5500 images from the archives of two space missions to the planet. It's the biggest survey ever for atmospheric waves on the night side of Venus, and it's now a database that could hint at what's creating them.
Atmospheric gravity waves have been receiving increasing attention due to their role in transporting energy in planetary atmospheres. They may be one of the keys to explaining the mechanism that generates and maintains the super-rotation of Venus' atmosphere. However, they may not be the only source of waves, according to the researchers' analysis of archived infrared images obtained in 2007 and 2008 with the Visible Infrared Thermal Imaging Spectrometer on the European Space Agency's (ESA) Venus Express mission, and in 2016 with the Akatsuki mission's IR2 instrument, from the Japanese space agency JAXA.
Computer simulations of the atmosphere, with full physical models, and in which IA researchers are also actively involved, have shown that short-range differences in vertical wind speed or direction can affect the wavelength and direction of atmospheric waves and in a way that is consistent with what this study found about the properties of these waves.
Precisely, the study of vertical winds, and vertical transport, gained a new window. It turned out that two measurement techniques used simultaneously but millions of kilometres apart, with telescopes on Earth and probes just above Venus, have been probing the speed of horizontal winds at two slightly different altitudes. This result was published in a second paper led by IA (Machado et al. 2021).
Overall, these results illustrate the important results that the IA team is obtaining in the study of solar system atmospheres, opening the door to a strong participation in future missions such as ENVISION (ESA), expected to be launched in 2030.



Images obtained in infrared by the IR2 camera of the Akatsuki spacecraft, from the Japanese space agency JAXA, processed, inverted and colorized. In them it is possible to observe examples of atmospheric waves. Credits: PLANET-C Project Team/José Silva et al., 2021.

Discovery of a composition link between planets and their host stars

Research dome by the team has discovered that the composition of known rocky planets is closely related with the one we observe on their host stars. This result sheds new light into the processes of planet formation and evolution and can be used as input for models of planet chemistry.

Newly formed stars are surrounded by a protoplanetary disk, with a fraction of the material in this disk condensing into blocks of planet formation and the rest eventually falling to the star. Because of this common origin, it was assumed that the composition of these planetary “bricks” and low-mass rocky planets would be similar to the composition of the parent star.

However, until now the only reference available was our own Solar System and for this, the composition of the main rock-forming elements in the telluric planets (with the exception of Mercury), such as magnesium, silicon or iron, is similar to the composition of the Sun.

In a new investigation published in the prestigious journal Science, an international team led by IA (Adibekyan et al. 2021) managed to establish, for the first time, a correlation between the composition of rocky exoplanets and the composition of their parent stars.

This study was based on measurements of mass and radius, which were used to calculate the density of the planets, as well as on the measurement of precise and detailed chemical abundances in the planet-host stars. High-resolution spectra, obtained with the most advanced spectrographs, mounted at large observatories across the planet, at ESO's La Silla and Paranal observatories, Mauna Kea and Roque de los Muchachos, were used.

Interestingly, the team also demonstrated that, contrary to what was supposed, this relationship is not direct. First, the chemical relation has not a 1:1 link. Furthermore, the team revealed one intriguing result. They found that there is a gap between the iron fraction of super-Earths and super-Mercuries, which gives evidence that these planets represent distinct populations in terms of composition, which could be due to differences in the process of their formation.

Understanding the relationship between the composition of stars and their planets has been a central topic of IA research for over a decade, and one of the research lines where the team has the highest international impact.

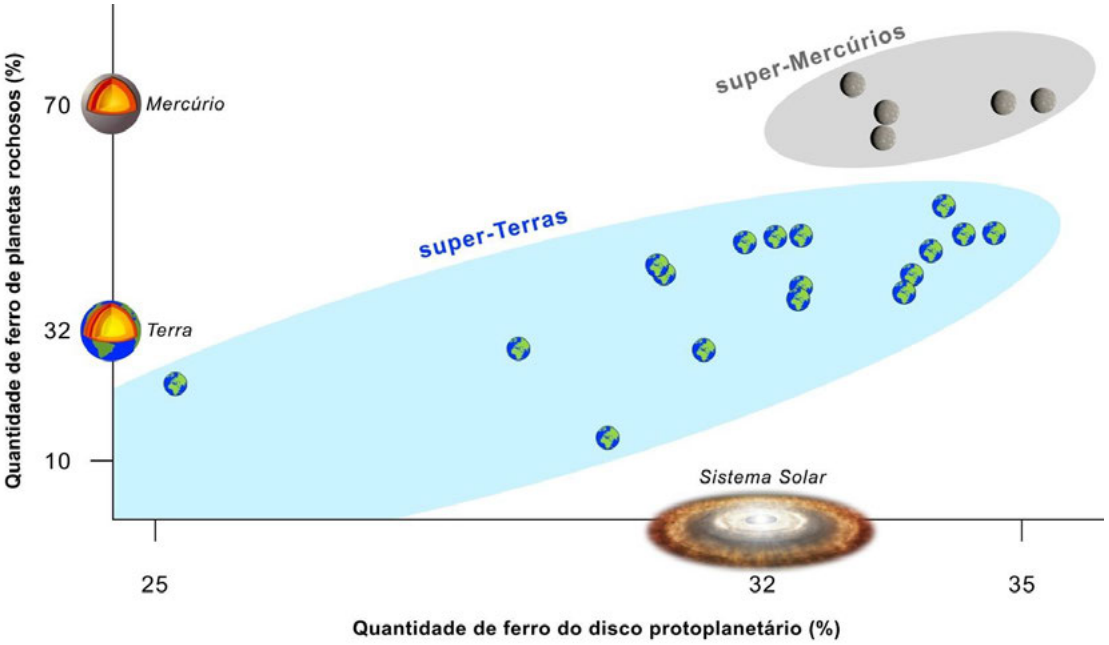


Figure: Percentage of iron from the analysed planets and from the protoplanetary disk where the planets formed. (Credit: Adibekyan et al. (2021)/IA).

A Unique catalogue of exoplanet-host stars

The IA team develops and maintains a unique catalogue of properties of stars with planets. This catalogue, named "SWEET-Cat" (http://sweetcat.iastro.pt), contains invaluable data that is key to the characterization of detected exoplanets.

Accurately characterising stars is crucial to discovering and characterising the exoplanets that orbit them. High-precision stellar parameters can help, for example, in distinguishing between the discovery of Neptune-like planets or planets similar to our own Earth.

SWEET-Cat is, in this sense, a unique catalogue in the world, as it contains, for a list of stars with planets that is constantly updated, stellar parameters that were always derived with the same method. At present, SWEET-Cat allows the community to query homogeneous and high-precision parameters of more than nine hundred stars with exoplanets.

The SWEET-Cat catalogue was originally presented in 2013, but in 2021 it was strongly updated (Sousa et al. 2021): it now also includes information on the use of parallax from the GAIA space mission (ESA). This allowed the team to increase the number of stars that have reliable data by more than 40%, and more accurately determine their masses and radii. This update was recently published in the journal Astronomy & Astrophysics.

The SWEET-Cat catalogue illustrates very clearly the long-term work done by the IA team to develop studies of the relationship between the properties of stars and their planets.

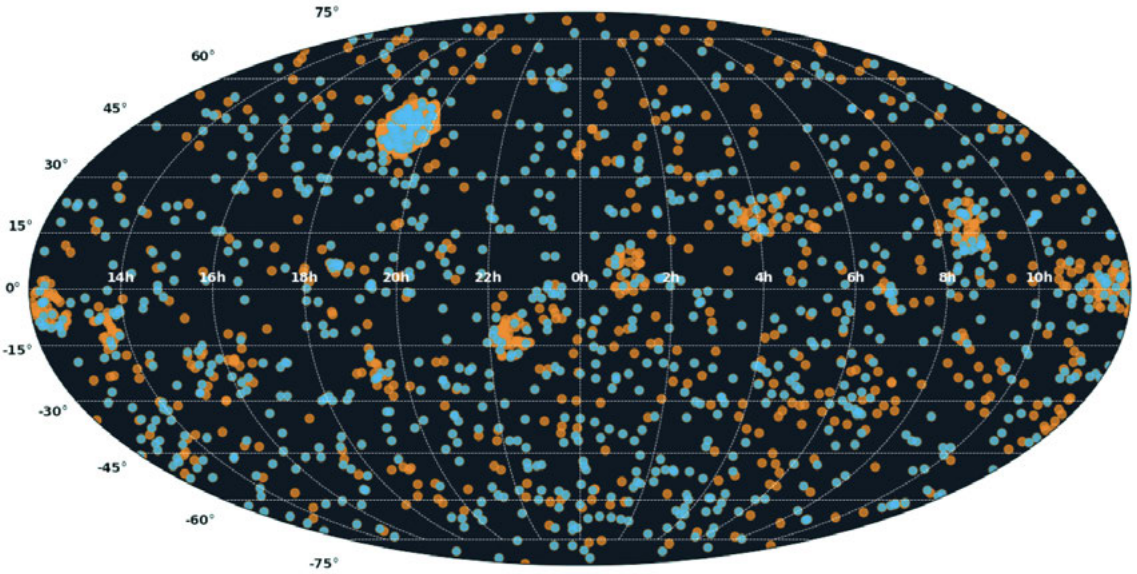


Figure: Map of the entire sky (Northern and Southern hemispheres) with the position of stars with planets in the SWEET-Cat catalogue. The yellow balls represent inhomogeneous parameters, while the blue ones are homogeneous parameters. (Credit: Sérgio Sousa - IA & U. Porto).

Thematic line meetings, Journal Clubs and other activities

In 2021, as for the previous years, the IA-planet line maintained a regular journal club and team meeting agenda. Team meetings and journal clubs are organised every two weeks. Meetings include a presentation of “general information”, as well as a short presentation of the work being carried out by one PhD student, followed by discussion. This format helps the whole team to be acquainted with the research that is being carried out and helps the students to develop presentation skills and identify potential problems and solutions in his/her research project. Journal clubs include the presentation of recent research papers, followed by discussions.

All this information is kept up-to-date in the new team web pages (http://planetas.iastro.pt).

Due to the covid-19 situation, all regular team meetings and journal clubs were performed remotely via Zoom. The regular contact helped to minimise the impact of the confinements and decreased human contact in the team's activities.

We also organised our annual team meeting (called "2-DEMOC"), where the team strategy and plans (both scientific and organisational) were discussed. This year's event took place in Porto, and allowed the integration of the new IA Coimbra node members in the team.

In 2021 the team also started a new series of workshops (`Planetary System's Days @ IA''), meant to present all scientific results obtained over the previous months and discuss defined scientific hot or strategic topics. Two such workshops were organised in 2021, to which all IA members were invited.

Team members actively participated in different public outreach activities, including public talks and debates in schools and online, as well as other outreach events. In this context, the team has also made a public outreach page on Planetary Systems (https://outrosmundos.iastro.pt), where information in

Portuguese is provided about planetary system's science as well as the discoveries where the team is involved.

In 2021, 4 PhD thesis and 2 MSc thesis were successfully finished (several others ongoing):

- "Detection and characterization of planets orbiting oscillating red-giant stars with NASA's TESS mission", by Filipe Pereira (PhD)
- "Looking for rings and tides in transiting planets", by Babatunde Akinsanmi (PhD)
- "Radial velocity data analysis and optimization of observations for the ESPRESSO", by Saeed Hojjanpanah (PhD)
- "From Solar System to exoplanets - atmospheric characterization and search for chemical disequilibrium compounds", by Ruben Gonçalves (PhD)
- "Composition of terrestrial planets orbiting M dwarfs", by Barbara Soares (MSc)
- "Chemical composition of super-massive planet hosts: the clue to their formation", by Mariana Reis (MSc)

and one ERASMUS+ PhD student also joined the team (for a 4-month stay, between November 2021 and February 2022). Finally, a number of undergraduate students (Barbara Oliveira, Yuri Damasceno, Ana Paulino, Telmo Monteiro, Afonso Mota, Bruna Fena, Rafael Silva, Diogo Quirino, Bernardo Campilho, Antonio Miguel Braçais Correia) also did short research work/internships with team members.
Team funding comes mostly from IA "strategic funding" as well as from 3 running FCT projects. Furthermore, funding for our participation in the PLATO and ARIEL missions was secured through PRODEX for the 2022-2023 period. We note, however, the PRODEX funding covers only the "project level activities".

Nuno Santos
Group Leader

Report from the Group

Towards a comprehensive study of stars

The year 2021 witnessed the expansion of IA with the integration of the new Coimbra node. This had a direct impact on the research scope of our Group, as extensive expertise on the fields of solar physics and space weather was now at our disposal. Together with a change in the Group leadership in July 2021, this naturally led to a revision of the Group's high-level structure and strategy. Our research activity thus currently revolves around four main thematic lines: *Star Formation*, *Stellar Physics*, *Stellar Populations* and *The Sun and the Heliosphere*.

The *Star Formation* thematic line focuses on two main areas of research:

- Star formation in the context of the large Galactic scale of the interstellar medium, focusing on the role of filamentary structures in generating the observed mass distribution from low- to high-mass stars, and the impact of feedback from massive stars.
- A detailed study of the evolution of individual pre-main-sequence stars and their circumstellar disks.

Over the past year, we have analysed submillimetre dust emission observations (using data from ESA's Herschel Space Observatory) of star forming regions in order to identify and derive physical properties of filaments, dense cores and protostars. Moreover, we continued performing infrared and millimetre studies (VLT and ALMA) of massive star formation and studied the impact of their feedback to trigger new generations of stars in the compressed layers of the cold molecular medium.
The characterization of pre-main-sequence stars and their environments and, in particular, T Tauri stars (TTSs), is being achieved using several strategies, namely, photometric analysis of circumstellar disks around Classical T Tauri stars (cTTSs), spectroscopic studies (UV and visible) of signatures of outflows and accretion rates, and spectropolarimetry observations using SPIRou@CFHT of the complex magnetic field structures permeating TTSs. The team's involvement in SPIRou is of particular significance, with one of its members being part of the consortium's Steering Committee. We are also involved in the modelling of the topology of the magnetospheric region surrounding these objects, in devising simulations for the connection between accretion and outflows that ultimately control their evolution, and in the determination of mass accretion rates and angular momentum losses.

The *Stellar Physics* thematic line focuses on understanding the physical processes that take place in stars, from the stellar interior to the surface.
The team has a large expertise in data analysis and stellar modelling, and vast experience in probing the physics of stars. We develop, test and apply seismic inference tools aimed at retrieving information on chemical mixing and segregation in order to test, improve and validate new formulations being implemented in stellar evolution models.
The seismic analyses conducted by the team allow the measurement of the stellar mass, age, metallicity and helium abundance, the depths of the convective and helium ionisation regions, as well as the properties of stellar cores. Furthermore, we also measure and study rotation and magnetic activity in stars, both through asteroseismology and low-frequency brightness variations, in order to

characterise stellar magnetic cycles and their driving mechanisms. Our research in stellar physics has strong connections with the evolution of stellar systems and their interaction with the circumstellar environment, including planets.
In the context of asteroseismology, we continue to be actively engaged in international consortia related to the NASA space missions *Kepler*/K2 and TESS. The exploitation of the seismic data from TESS is carried out predominantly in the context of the international consortium TASC (TESS Asteroseismic Science Consortium), in which our team is strongly involved, with representation on the Steering Committee and co-leadership of one of its working groups. Furthermore, our team continues to be strongly involved in the preparation of the stellar science component of PLATO, with responsibilities in the design, implementation, and validation of sections of the Stellar Analysis System (SAS) pipeline, leading work packages in the framework of both the PLATO Science Management (PSM) and the PLATO Data Center (PDC). The team has also been contributing to the Ariel (ESA) consortium, in the context of which it is responsible for the determination of ages, masses, and radii of the stars in the mission's Reference Sample.

The *Stellar Populations* thematic line focuses on the precise characterization of solar-type and red-giant stars, which provides precious information that can be readily applied to several areas of research, including Galactic archaeology and Galactic chemical evolution.
The team has a vast experience in using high-resolution spectroscopy to determine stellar atmospheric parameters (namely, effective temperature, surface gravity, and metallicity), as well as the detailed surface chemical compositions of stars, which are then used to investigate the interstellar medium's elemental enrichment history across different regions of the Milky Way (or Galaxy). The team further combines the chemical compositions of stars with accurate asteroseismic age estimates to study the formation and evolution of different stellar populations of the Galaxy and of the Milky Way as a whole.
We continue to be actively engaged in several international consortia, including PLATO, Ariel, HIRES@ELT, the Maunakea Spectroscopic Explorer (MSE), ESPRESSO@VLT, NIRPS@ESO 3.6-m Telescope, SPIRou@CFHT, and the *Gaia*-ESO Survey (concluded), among others. Of particular note, the HIRES project successfully passed its Phase A and has started Phase B (Preliminary Design) in late 2021. Our team has a strong involvement in this project, playing a key role in the development of its scientific priorities and definition of top level requirements.

The Sun and the Heliosphere thematic line focuses on studying the solar atmosphere as well as the influence of solar activity on the heliosphere and the Earth's atmosphere, also known as space weather.
The team has vast experience in image processing, radiative transfer inversion, magnetohydrodynamic wave detection and analysis, and machine learning. We continue to apply these techniques to a variety of data sets, e.g., to solar spectropolarimetric observations in order to study the solar atmosphere, and to *in situ* observations of GNSS (Global Navigation Satellite System) signal disturbances, the Earth's magnetic field etc., to better understand how solar activity influences the Earth and near-Earth heliosphere.
We continue to participate and collaborate in several national and international projects. Members of the team are leading the Portuguese participation in the European projects SWATNet and SWAIR, are contributing actively to the EST Preparatory Phase, are building the first Portuguese solar

spectropolarimeter, and are also developing the first detailed regional model of the ionosphere. We are also maintaining collaborations in the context of the SUNRISE and Solar Orbiter missions. Our participation in EST is of particular strategic importance. The Portuguese contribution to the project focuses on developing the Integral Field Spectropolarimeter based on Image Slicer, one of the team's members being Co-PI of the instrument.

Scientific highlights for 2021

1. PLATO hare-and-hounds

In Cunha et al. (2021, Monthly Notices of the Royal Astronomical Society, 508, 5864), the authors compare different approaches to the asteroseismic inference of stellar properties of main-sequence solar-like pulsators based on a pre-computed grid of models. The aim is to understand the accuracy and precision that may be expected on the inferred properties and identify critical aspects of the inference process that may need further development. Among other outcomes, the study points to the need for an extensive characterization of systematic errors resulting from model deficiencies and the importance of conducting an extensive study on the impact of the degradation of seismic data as less bright stars are considered. This work stems from our involvement in the PLATO Science Management (PSM), in the context of which we have responsibilities in the design of sections of the Stellar Analysis System (SAS) pipeline.

2. The Galactic chemical evolution of Carbon

In Delgado Mena et al. (2021, Astronomy & Astrophysics, 655, A99), the authors derive carbon abundances for FGK dwarf stars in the HARPS-GTO sample, one of the aims being to study the Galactic chemical evolution of this element. They find a clear separation in terms of [C/Fe] between the thin- and thick-disk populations, similarly to what has been found for α elements. They then go on to show for the first time that high-α metal-rich stars also have enhanced [C/Fe] ratios when compared to thin-disk stars of similar metallicity, a trend that is observed up to a metallicity of ~0.2 dex. Moreover, the [C/Fe] ratio shows an increasing trend with stellar age with a linear slope of 0.019 dex/Gyr, revealing the potential of abundance ratios involving carbon as age proxies.

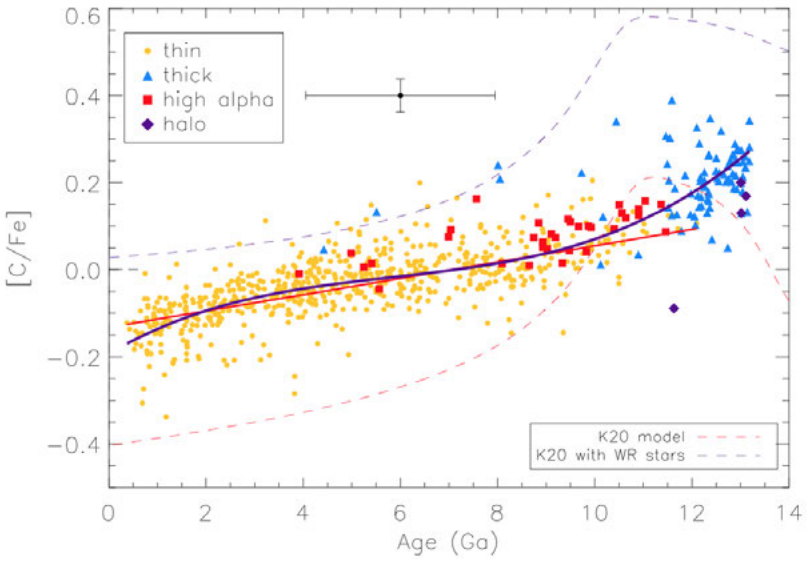


Figure 1: [C/Fe] ratio as a function of age. From Delgado Mena et al. (2021).

3. An astrophysical solution to the Lithium problem?

In Deal et al. (2021, Astronomy & Astrophysics, 653, A48), the authors employ a self-consistent perturbative analysis of the effects on Big Bang Nucleosynthesis (BBN) of the relevant theoretical parameters, including variations of nature's fundamental constants, to gain insight into the well-known Lithium problem (i.e., the fact that the predicted abundance of Lithium-7 exceeds the observed one by a factor of a few). The authors quantify the amount of depletion needed to solve the Lithium problem and show that depletion mechanisms at work during stellar evolution, namely, transport processes of chemical elements, are able to account for it. Specifically, the combination of atomic diffusion, rotational-induced mixing, and some amount of penetrative convection allows reproducing the Lithium surface abundances of Population II stars, starting from the primordial Lithium abundance. This tentatively points to an astrophysical solution to the Lithium problem, with the aforementioned transport processes likely being the dominant contribution to its solution.

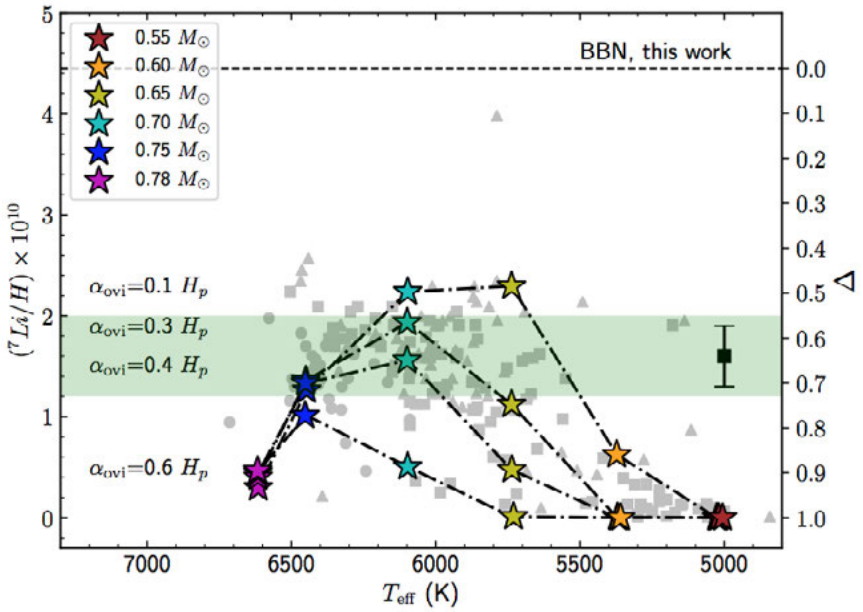


Figure 2: Lithium abundance for stellar models containing atomic diffusion, rotation, and penetrative convection. From Deal et al. (2021).

4. Machine learning applied to spectropolarimetric observations of the Sun

In Gafeira et al. (2021, Astronomy & Astrophysics, 651, A31), the authors advocate the use of convolutional neural networks (CNNs) in initialising Stokes profile inversions, hence enhancing the efficiency of such inversions and reducing computational cost. This addresses the challenges posed by the ever-growing volume of scientific data from current and upcoming solar observatories (e.g., DKIST and EST), which require simultaneously complex and fast inversion codes. The authors focus on applying CNNs to the inversion of local thermodynamic equilibrium (LTE) Stokes profiles, finding that CNNs allow to significantly reduce the number of inversion cycles when used to compute initial guess model atmospheres. Consequently, the computational time decreases by a factor of two to four compared to conventional approaches.

5. Asteroseismology made in Iberia

The *8th Iberian Meeting on Asteroseismology — Laying the groundwork for the road ahead* took place in October 2021 and was organised by Group members. The meeting gathered 72 registered participants from Iberia and beyond. Following the successful reinstallment in 2020 of the Iberian Meeting on Asteroseismology series, we gave continuity to this series by welcoming to this meeting the Iberian community and its diaspora — as well as some of our international collaborators — working on asteroseismology and related fields. This was a place to foster new collaborations and consolidate existing ones, discuss the challenges lying ahead, and find new, joint funding opportunities. The science program was multifaceted. At its core were a series of hands-on projects (7 in total). Hands-on projects took the form of either (i) self-contained, focused projects, (ii) the continuation of an ongoing project, (iii) or simply the exploitation of a novel idea. Meeting participants were free to join any project of their choice and, to guarantee that projects would run smoothly, we have created dedicated Zoom rooms, Slack channels, and cloud storage. We had two different types of talks during the meeting. During the opening session, we heard about the several institutes across Iberia where asteroseismology has a strong presence. Spread over the following three days, we had a number of talks (14) by young scientists. The rationale for this had to do with the pandemic and the increasing difficulty faced by young scientists in getting their work noticed by the community. Finally, we closed the meeting with a discussion on funding opportunities and a round table on a possible future joint application to Horizon Europe. The purpose of this round table was to sound out the community, identify the right funding opportunity(ies), and broadly identify the science case, with the aim of formalising our intents during the next Iberian meeting, where we will hopefully meet in person.

Figure 3: Poster of the *8th Iberian Meeting on Asteroseismology*.

Group meetings, Journal Clubs and other activities

We start by providing an overview of the internal procedures and meetings. Next, we highlight the main activity indicators for the year 2021, including funded projects, vivas, organisation of conferences and workshops, and outreach.

Regular meetings/activities

We hold biweekly Group meetings, a forum for discussing Group-related issues and strategy. These are held together with the Journal Club. Moreover, we hold so-called Stellar Physics meetings on a biweekly basis, a science forum for presenting and discussing work conducted by Group members on stellar/solar physics. In 2021, we instated Stars Day, a half-day science meeting highlighting the work conducted by Group members and fostering debate. Stars Day is meant to be an annual event (to be combined with a Christmas lunch in the post-pandemic) and is organised by the grad students. Finally, we also hold an annual 'SOAR analysis' meeting prior to IA-ON.

Website

The Group's new website was published in December 2021 and can be found at https://estrelas.iastro.pt/en

Funded projects

FCT R&D projects (ongoing in 2021):

- 1 project (regular).
- Previous call (2021): 6 projects were submitted (5 regular and 1 exploratory). One project (exploratory) was retained for funding.

Estímulo and *Investigador FCT* (ongoing in 2021):

- 2 *Investigador FCT* contracts ended in December 2021 (not accounting for extensions).
- 3 *Estímulo* contracts (1 Junior, 1 Assistant, and 1 Associate).
- Previous *Estímulo* call (4th edition): 2 successful applications (1 Junior and 1 Assistant). This amounts to 5 successful applications in the first four editions.

European funding (ongoing in 2021):

- MW-GAIA COST Action (Co-I).
- SWATNet — MSCA Innovative Training Network (Co-I).

Other funding (ongoing in 2021):

- OREO (PI).

PhD/MSc vivas

PhD:

- *Detection and characterization of planets orbiting oscillating red-giant stars with NASA's TESS mission* — Filipe Pereira.

MSc:

- *The star-disk interaction in Young Stellar Objects* — Hernán Asorey.

Organisation of conferences/meetings/workshops

- 1st i4s — Iberian Space Science Summer School.

- Space Summer School 2021.
- COSPAR International Space Weather Action Teams (ISWAT) 2nd Working Meeting (Part 1).
- 8th Iberian Meeting on Asteroseismology (Imas).

Outreach

- 2 press releases.
- Partnership with National Geographic Portugal: 3 articles by Group members (1 of which by a PhD student).
- Partnership with SAPO TEK: 2 articles by Group members.
- *O Universo Online*: 2 sessions hosted by Group members.
- IAstro Summer Internship program: 4 projects by Group members during 2021 edition.
- *Semana da Leitura 2021 — Como o céu brilha nas palavras*: participation of 2 Group members.
- *Dia Internacional das Mulheres e Raparigas na Ciência 2021 — Astronomia no Feminino*: Participation of 2 Group members.
- *Dia Nacional da Cultura Científica 2020 — Livros Top – Ciência e Literatura*: Participation of 1 Group member.

Tiago Campante
Group Leader

Report from the Group

The assembly history of galaxies resolved in space and time

The adverse conditions created by the COVID19 pandemic have led to significant challenges for the Group and greatly impacted its scientific work during 2021. Notwithstanding this fact, the Group has continued the implementation of its strategic plan, intensifying its efforts toward the exploration of the formation history of galaxies and their structural components, of the genesis and growth of supermassive black holes (SMBHs) in galactic nuclei and their influence on the assembly history of galaxies, the mechanisms triggering and regulating starburst activity and its role on the galaxy stellar mass growth, and the influence of the environment on galaxy evolution.

These science goals which are being pursued by a team of 13 researchers, 11 collaborators and 10 students, are served by the participation of IA with leadership roles in the instrument consortia of MOONS@VLT, BlueMUSE@VLT, MOSAIC@ELT of ESO, and ESA missions with key relevance to the strategy of the TL (Euclid, Athena), as well as by the parallel development of highly optimised computational tools for the scientific exploitation of multi-wavelength data for galaxies near and far.

The growth of SMBHs and their observational manifestations as Active Galactic Nuclei (AGN) is being investigated by the Group both at highest redshifts and in the nearby universe. The emergence of the very first powerful AGN in the Universe, and how they shaped the earliest galaxy evolution is being studied through sub-mm observations with IRAM and the revolutionary ALMA, and by post-processing cosmological simulations to obtain quantitative predictions on the number and detectability of early SMBHs at X-rays and radio wavelengths. Building upon its expertise on the analysis and interpretation of multi-wavelength data, and as part of a coherent strategic roadmap, the Group is developing new observational discriminators for the detection of proto-AGN at the Epoch of Reionization (EoR). It also acts as a strong driver in the development of the future ASKAP's Evolutionary Map of the Universe survey, through the IA-lead Key Science Project "Radio AGN in the EoR'' and is represented at the Board and Science team level in ESA's future X-ray mission, Athena.

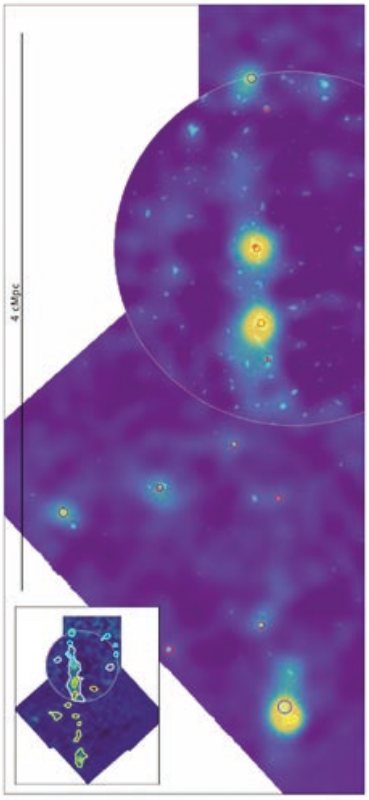
At low and intermediate redshift (z), the AGN phenomenon is being studied using the currently most powerful telescopes and instruments, most notably the Multi Unit Spectroscopic Explorer (MUSE) at ESO-VLT. Special emphasis is being laid on the study of quasars surrounded by gigantic Lyman-α halos and the definition of new diagnostics for constraining the physical conditions and excitation mechanisms in the nebular component of these extreme environments. This line of research is further supported by a comparative analysis of gas kinematics and excitation properties obtained from integral field spectroscopy (IFS) with predictions from cosmological simulations incorporating AGN feedback, and through the ongoing further development of IA's spectral synthesis code FADO with the capability of self-consistently modelling stellar and nebular emission jointly with an AGN power-law component. FADO, together with other tools developed at IA, are being used to prepare the scientific exploitation of MOONS (the Multi Object Optical and Near-infrared Spectrograph for the VLT), an instrument the IA co-leads and which is expected to start its operation in 2023.
During 2021, the team continued having a key involvement in the preparation of guaranteed time observations with MOONS and in the definition of strategies for the reduction and analysis of data from

it. IA researchers assume major roles in several MOONS Science and Technical Working Groups (WGs), including the co-leadership of the AGN WG and the technical WG-1, and have an active role in the scientific WGs on Physics of the ISM, Passive galaxies and stellar continuum, Galaxy environment, Large-Scale Structures, High-z Universe and the EoR, Clusters/Protoclusters, and in the technical WGs on Mock Catalogues from Simulations, Determination of Redshift and Physical Parameters from Spectra, and on the Determination of Environmental Parameters.

Another important field of the activities of the TL centres on spatially resolved investigations of galaxies with IFS and deep multi-band photometry. Using MUSE and the CALIFA and MaNGA IFS galaxy surveys, team members are investigating a wide range of fundamental issues in extragalactic research, including the build-up history of galaxy bulges and the physical drivers of their inside-out star formation quenching, age and metallicity patterns in spiral and elliptical galaxies, cooling flows and ram pressure stripping effects in galaxy clusters, gas kinematics and excitation mechanisms in elliptical galaxies, the evolution of the ionising photon efficiency across cosmic time, massive Wolf-Rayet stars and the diffuse ionised gas in star-forming galaxies, and the nature of ultra-faint galaxies. Furthermore, using ALMA, MUSE and FADO the team is studying the action of starbursts on the molecular gas phase in extremely metal-poor dwarf galaxies, which may be considered the best local analogs of the first proto-galactic units that emerged at the EoR. The activities of the team also encompass the development of Machine Learning tools for the identification of high-z AGN and the characterization of galaxies from the Euclid Galaxy Legacy Survey , which is co-led by IA.

Scientific Highlights for 2021

1. The cosmic web back to 1.3 billion years after the Big Bang detected in Lyman-α



The IA researcher Jarle Brinchmann has participated in an unprecedentedly deep exploration of Lyα emission at high redshift. This project, which used a total integration time of 140 hours with MUSE@VLT led to the discovery of diffuse extended Lyα emission at $3.1<z<4.5$ (i.e., between 1.3 and ~2 Gyr after the Big Bang) tracing cosmic web filaments on scales of 2.5–4 Mpc in comoving scale (Bacon… Brinchmann et al. A&A 647A, 107B). Among the 22 overdense regions identified, five are likely to harbor very extended Lyα emission at high significance with an average surface brightness of 5 × 10–20 erg s–1 cm–2 arcsec–2. Quite importantly, 70% of the total Lyα luminosity from these filaments comes from beyond the circumgalactic medium of any identified Lyα emitter. Fluorescent Lyα emission powered by the cosmic UV background can only account for less than 34% of this emission at $z \approx 3$ and for not more than 10% at higher redshift.

Fig.1: Extended diffuse Ly α emission at z=3.07 in one of the (22) overdensities discovered in the MUSE UlttraDeep by Bacon … Brinchmann et al. (2021).

A key insight from this study has been that this diffuse Lyα emission requires the presence of a large population of ultra low-luminosity Lyα emitters (< 1040 erg s−1), provided that the faint end of the Lyα luminosity function extends down to luminosities lower than 1038 – 1037 erg s−1, and the clustering of these Lyα emitters is significant (filling factor < 1/6). If the discovered Lyα emitters are powered by star formation, then this implies star formation rates (SFRs) < 10−4 $M_\odot$ yr−1. These observations provide the first detection of the cosmic web in Lyα emission in typical filamentary environments and the first observational clue indicating the existence of a large population of ultra low-luminosity Lyα emitters at high redshift.

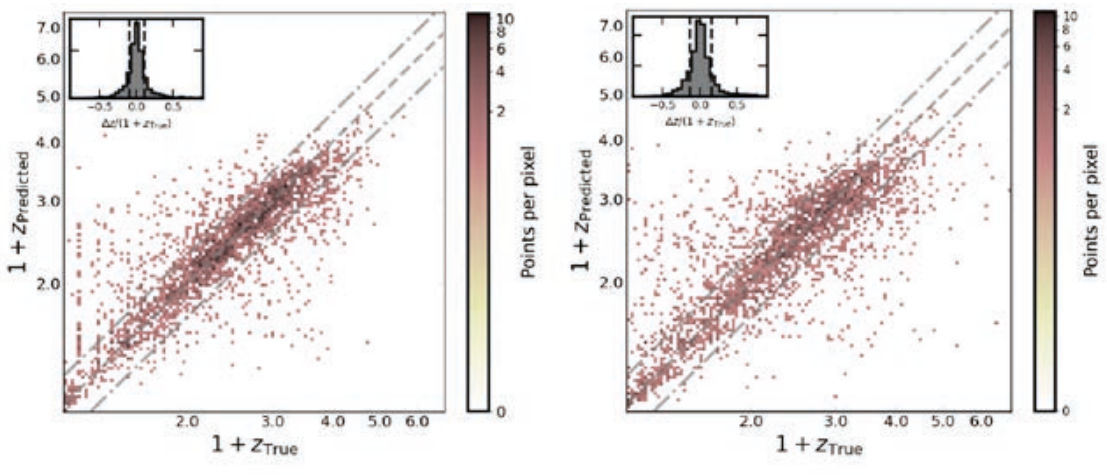
2. Using Machine Learning tools to explore new redshift indicators for radio-powerful AGN

AGN are relevant sources of radiation that might have helped realising the Universe during its early epochs. Recent studies have shown that, for epochs earlier than z~5, the number density of SMBHs is on the order of a few hundreds per square degree. Latest observations place this value below 300 SMBHs at z≥6 for the full sky.

To overcome this gap, it is necessary to detect large numbers of sources at the earliest epochs. Given the large areas needed to detect such quantities, using traditional redshift determination techniques (spectroscopic and photometric redshift) is no longer an efficient task. Machine Learning (ML) might help obtaining precise redshift for large samples in a fraction of the time used by other methods. Motivated by such considerations, the IA team has developed and implemented a ML model which can predict redshift values for WISE-detected AGN in the HETDEX Spring Field and in the Stripe 82 Field. A recent study (Carvajal, Matute, Afonso et al. 2021, MDPI Galaxies, vol. 9, 86) has succeeded in obtaining a median prediction error of 0.1162 and an outlier fraction of <12%, highlighting the potential of automated ML-supported searches for high-z AGN.

A parallel project by the team led to the development and validation of a ML technique for estimating galaxy redshifts in the Euclid Galaxy Legacy Survey (Humphrey et al. 2021, under internal review within the Euclid consortium) and the efficient discrimination between high-z quasars and foreground Galactic stars (Cunha & Humphrey, in prep.).

This is part of a larger effort by the team for Euclid (Humphrey… Cunha & Humphrey in preparation)



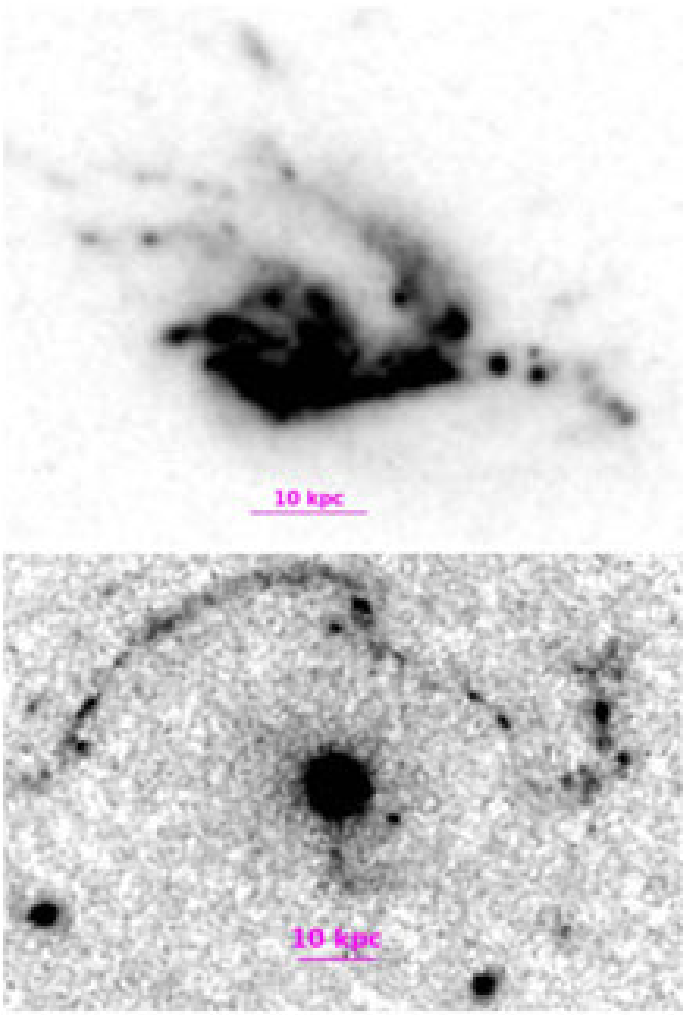
(a) HETDEX Spring Field validation set.

(b) Stripe 82 Field sample.

The development of ML tools and improved observational discriminators for AGN is fundamental to the strategy of the Group toward exploration of the genesis of SMBHs in the early Universe. Of relevance to that goal is the exploitation of AGN with existing observing facilities. Some examples in this regard include the discovery of two giant radio galaxies (GRGs) with enormous physical sizes of 2.4 Mpc and 2.0 Mpc at redshifts z~0.17 and ~0.34 using the MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) survey (Delhaize … Afonso et al. 2021, MNRAS 501, 3833), the study of 36 high-z radio AGN candidates with the Atacama Compact Array (Messias … Matute … Afonso … Amarantidis et al. 2021, MNRAS 508, 5259), and the validation of the data processing strategy for MIGHTEE, a novel galaxy evolution survey that uses simultaneously radio continuum, spectropolarimetry and spectral line observations from the South African MeerKAT telescope (Heywood … Afonso et al. MNRAS, 2021 submitted).

3. Influence of the environment on galaxy evolution

The team has continued its studies of the action of the environment on galaxy evolution, both in clusters and compact galaxy groups, and in individual galaxy pairs in a strong gravitational interaction.



Durret, Chiche, Lobo & Jauzac (2021, A&A 648A, 63D) have searched a sample of 40 galaxy clusters from the DAFT/FADA and CLASH surveys at 0.2<z<0.9 for jellyfish galaxies, and identified on HST ACS images ~100 such systems with clear signs of ram pressure stripping and morphological distortions. Based on best-fitting synthetic spectral energy distribution to multi-wavelength data they inferred the stellar mass of their sample galaxies to 109 – 1011 $M_\odot$, and their SFR to 0.1–60 $M_\odot$ yr–1. Interestingly, more than half of the sample in one of the studied clusters (MACS0717) shows intense star-forming activity with specific SFRs as high as >10–9 yr–1. The sample of these newly identified jellyfish galaxies constitutes a valuable basis of future work.

Fig. 3: Example of a jellyfish galaxy (upper panel) and a morphologically distorted spiral galaxy (lower panel) from the sample by Durret, Chiche, Lobo & Jauzac (2021), demonstrating the action of ram pressure stripping and gravitational interactions on the evolution of galaxies in clusters.

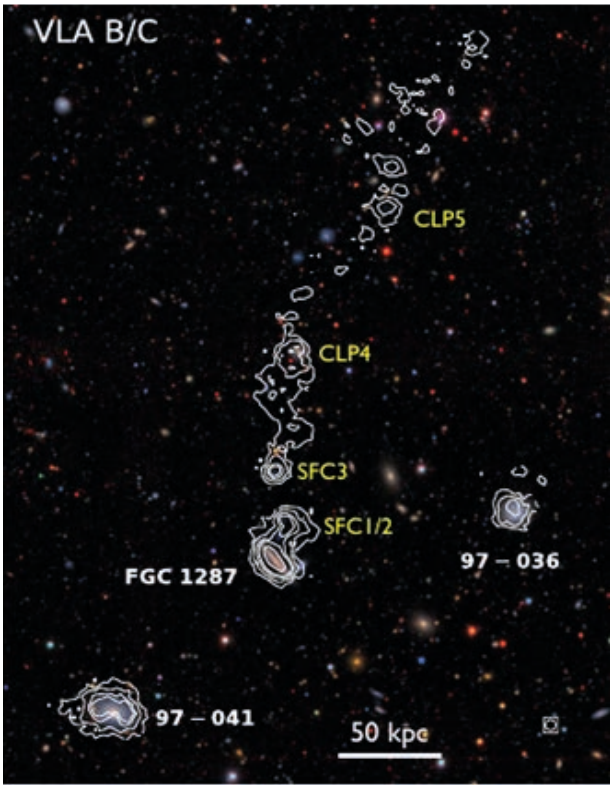


Fig. 4: FGC 1287 galaxy triplet: HI VLA B/C-configuration HI column density map as contours on a composite SDSS g, r, i-band image, coded as BGR. HI contours are at column densities of 0.5, 1.6, 3.1, 4.7, 6.2, 9.3, and 12.5 x 10^{20} atom cm^{-2}. The three HI detected galaxies are marked together with the projected positions of principal HI clumps in the FGC 1287 tail (from Scott … Lagos et al. 2021, MNRAS, submitted).

Further insights into the role of the environment on galaxy evolution could be gained through interferometric HI studies of the galaxy triplet FGC 1287 in the outskirts of the galaxy cluster Abell 1367. Scott … Lagos et al. (2021, MNRAS, submitted) have detected a 250 kpc long HI tail north-west of FGC 1287. The nature of this feature is enigmatic, given that observations with XMM-Newton do not reveal X-ray emission in the volume of the galaxy triplet, which places an upper limit of 2.6×10^{-5} cm^{-3} on the electron density and makes unlikely that the observed tail has resulted from the interaction of neutral hydrogen with the hot intracluster medium. In a similar context, Scott, Sengupta, Lagos et al. (2021, MNRAS 503, 39) used data from the Giant Metrewave Radio Telescope (GMRT) for a comparative study of the HI properties of two ultra-diffuse galaxies, one of those in the outskirts of a Hickson Compact Group and the other one truly isolated.

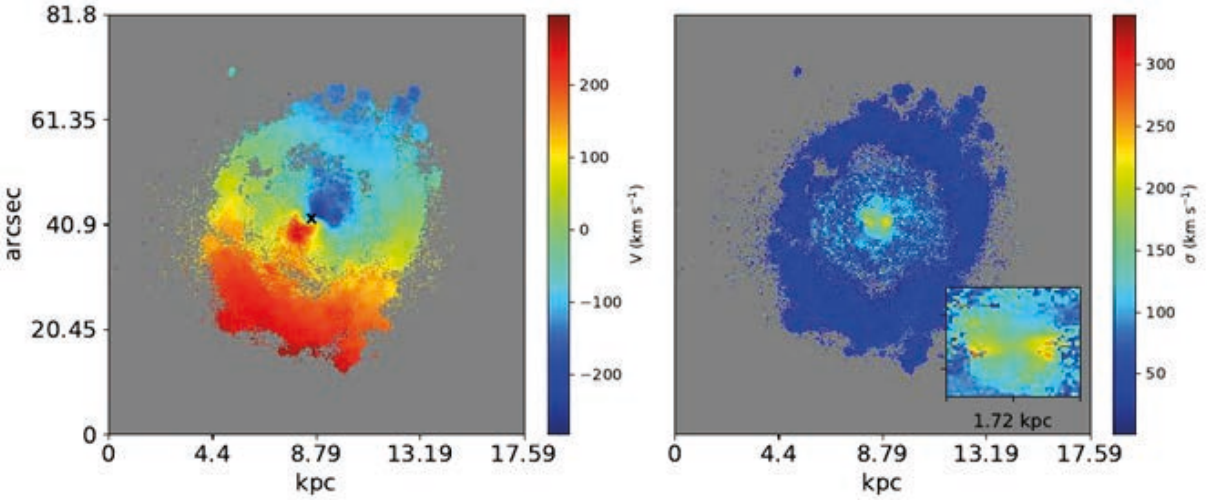


Fig. 5: Example of the analysis of groupdominant galaxies by Lagos … Scott et al. (2021, in prep.). Gas velocity (left panel) and gas velocity dispersion (right panel) obtained for the galaxy ESO0507-G025 from fitting the [NII] 6583 emission line. The position of the continuum maximum is indicated by the X symbol. A zoom into the velocity dispersion map of the nuclear region of the galaxy is shown in the inset panel. North is up and east is to the left.

A parallel line of investigation by the team focuses on the star formation history and gas excitation mechanisms in massive (>10^{12} $M_{\odot}$) galaxies in the densest known galaxy clusters (Pagotto .. Brinchmann et al. 2021, A&A 649A, 63P) and in group-dominant galaxies (Lagos … Scott et al. 2021, in prep.). Lagos et al., by applying the IA-developed spectral synthesis code FADO (Gomes & Papaderos 2017) to deep MUSE IFS data for 18 group-dominant galaxies (all of those classified as Ellipticals and S0) were able to accurately subtract the underlying stellar continuum and perform a thorough analysis of the gas-phase metallicity and excitation diagnostics. An insight gained from this study is that the centers of group-dominant galaxies typically show LINER-like emission-line ratios that possibly hint at an AGN, and that extranuclear star-forming regions in some S0s are chemically homogeneous. Various lines of evidence presented by these authors suggest that group-dominant galaxies likely acquired their cold gas via gas-cloud accretion and/or cooling flows.
Finally, the role of strong galaxy interactions on the star formation history and chemical patterns of galaxies was studied in the galaxy merger NGC 1487 by applying FADO to MUSE IFS data (Buzzo … Papaderos et al. 2021, MNRAS 503, 10). This study found flat and in some cases inverted oxygen abundance gradients that presumably reflect the combined effect of gas inflows and mixing of heavy elements within the turbulent gas medium of this galaxy merger.

4. Studying the nature of dark matter in ultra-faint dwarfs

Ultra-faint dwarfs (UFDs) contain very few stars relative to their dark matter (DM) content, with many cases of stars contributing less than 1% of the total mass of the galaxy. This means that they have a very small effect on the gravitational potential of the galaxy and they can be used as test particles in a DM dominated potential. For this reason UFDs are suitable laboratories to study the density profile of DM and distinguish between competing theoretical concepts, such as a cuspy NFW profile and a DM profile exhibiting a central density plateau. Jarle Brinchmann is the PI of a survey of a sample of UFDs using MUSE (MUSE-Faint). Recently, this project led to constraints on the DM density profile of Eridanus II (Zoutendijk, Júlio, Brinchmann, …, Vaz et al 2021, A&A, submitted), showing that if there is a core in this UFD it must be much smaller than those seen in more massive, star-forming dwarfs. This insight rules out modified DM as the origin of those cores.
A significant step forward has been possible through two MSc research projects completed at IA in 2021: a study of stellar kinematics for the borderline dwarf Leo T by the student Daniel Vaz has helped improving constraints on axion DM in a certain energy range by two orders of magnitude (Regis, Macro, Vaz, Brinchmann et al 2021; PhL 81436075R). Additionally, the student Mariana Julio has studied with MUSE the transition dwarf Antlia B to place limits on scalar field DM.

5. Star formation quenching at the centres of massive spiral galaxies

Our knowledge about the photometric and structural properties of bulges in late-type galaxies (LTGs) is founded upon image decomposition into a Sérsic model for the central luminosity excess of the bulge and an exponential model for the more extended underlying disk. A study led by IA researchers (Papaderos, Breda, Humphrey, Gomes, Ziegler & Pappalardo 2021, A&A in press) argued that the

standard practice of adopting an exponential model for the disk all the way to its center is inadequate because it implicitly neglects the well-established fact of star formation (SF) quenching in the centres of massive LTGs: Extrapolating the fit to the observable star-forming zone of the disk (outside the bulge) inwardly overestimates the true surface brightness of the disk in its central SF-quenched zone, consequently it leads to a systematic underestimation of the luminosity of the bulge. This effect (referred to as δ_{io}) was for the first time quantitatively studied by IA-researchers based on predictions from evolutionary synthesis models and by using the IA-developed tool RemoveYoung (Gomes & Papaderos 2016) to infer the luminosity contribution of young stellar populations in the bulge and disk. The IA team demonstrated that δ_{io} in massive LTGs can reach values of up to ~2.5 (0.7) B (K) mag, consequently the neglect of SF quenching in state-of-the-art galaxy decomposition studies introduces important biases inscaling relation involving bulge luminosities. Framed in the picture of galaxy downsizing and inside-out SF quenching, δio is expected to differentially impact galaxies across redshift and stellar mass M_*, thus leading to systematic and complex biases in the scatter and slope of various galaxy scaling relations. One conjecture made is that correction for the δio effect will lead to a down-bending of the bulge versus SMBH mass relation for galaxies below $\log(M_*/M_\odot)$~10.7. This could offer an element for understanding the scarcity and weakness of accretion-powered nuclear activity in low-mass spiral galaxies.

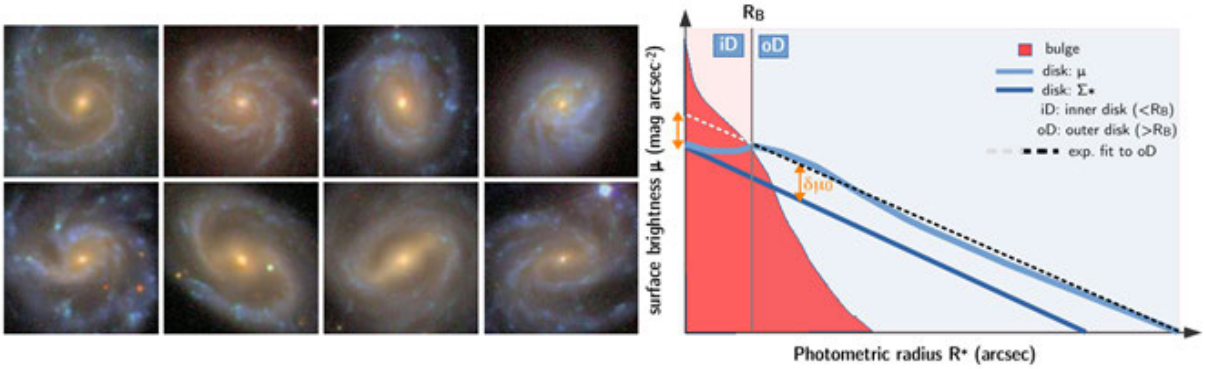


Fig. 6: **left**: SDSS true-color thumbnails illustrating the typical morphology of Milky Way-sized LTGs in the local Universe, with their central SF-quenched zone and the surrounding blue star-forming disk. **right**: Schematic representation of the bulge (shaded red area) and the disk (light blue) in a face-on late-type galaxy. The surface brightness profile of the disk results from the projection of an exponential stellar surface density $\sum_*$. (dark blue), whereby the mass-to-light ratio in the inner SF-quenched zone of the disk (iD) within the bulge radius R_B is higher than that in the outer ($R^* > R_2$) star-forming zone of the disk (oD). A consequence of this is that the central surface brightness of the disk is fainter by δμ0 mag than the value implied by inward extrapolation of the exponential fit to the outer disk (dashed line) and that standard bulge-disk decomposition overestimates the integrated magnitude of the disk within R_B by δio (mag). This in turn entails an over subtraction of the disk and an underestimation of the luminosity of the bulge (from Papaderos, Breda, Humphrey, Gomes, Ziegler & Pappalardo 2021, A&A in press).

Group meetings, Journal Clubs and other activities

The emergence of the COVID19 pandemic has forced the team to base almost its entire internal communication on video conferences and email, and resulted in various technical challenges related to the remote processing of large data sets being centrally stored at IA's servers. Despite these conditions, the team could largely maintain its productivity, further intensify internal synergy and establish new collaborations. Throughout 2021, the team maintained a busy schedule of weekly

Briefings in which the team's scientific work is discussed. Additionally, regular weekly journal clubs were also continued, for the discussion of recent, mostly non-IA, scientific results.

The dynamics of the team is also reflected in the continued development and intensive testing of Machine Learning and spectral fitting tools, which will strongly support its scientific activities in the context of Euclid, MOONS@VLT, MOSAIC@ELT and BlueMUSE@VLT, the organisation of the IA-internal workshop "*1st Galaxies Day @ IA"* (April 2021), and in the co-organization of the three-day online conference "*Massively Parallel Large Area Spectroscopy from Space*" (Co-Chair: J. Brinchmann) with 189 participants (June 2021).

Polychronis Papaderos
Group Leader

Report from the Group

Unveiling the dynamics of the Universe

This report highlights contributions in the main subjects of research in the cosmology group, centering around dark energy, modified gravity and cosmic defects. We focus essentially on the Euclid, ESPRESSO and LISA missions.

Euclid is a mission dedicated to the exploration of the dark universe through the measurement of the properties of the cosmological large-scale structure. IA is strongly involved in this mission, participating in the consortium board, in various Science Working Groups and in the Survey Design. This year several members and collaborators of the IA cosmology group have participated, sometimes as lead-authors, in the writing of more than 20 pre-launch key and standard papers, some already published in 2021, and others to be published next year. One of our members is now deputy of the Euclid Survey Working Group and the new Survey model owner.

The ESPRESSO spectrograph is an instrument of interest to several groups in IA. For cosmology, its main interest lies in the possibility of measuring variations of the fundamental constant. As planned, its data analysis for fundamental physics data was processed this year. This resulted in the paper "Fundamental physics with ESPRESSO: Precise limit on variations in the fine-structure constant towards the bright quasar HE 0515-4414" to be published in A&A, with authorship of several IA members.

LISA will be a large-scale space mission designed to detect gravitational waves. This year, the project for cosmic string parameter estimation has resumed, after a hiatus of almost two years due to the pandemic and a reorganisation of the consortium. The objective of this project is to provide templates for the different cosmic string models that may be probed with LISA and to start building a template catalogue for the mission. This project has now been adopted as a Work Package by the LISA science group. LISA Science white papers are in their final stages of preparation both for the cosmology working group and the fundamental physics working group; these have co-authorship of several team members.

This year the biennial edition of the "Review of Particle Physics" went live in December, with the section on Cosmological Parameters co-authored by one team member.

Scientific Highlights for 2021

1. **New constraint on the fine-structure constant variations**

   The strong intervening absorption system at redshift z=1.15 towards the very bright quasar HE 0515-4414 is the most studied absorber for measuring possible cosmological variations in the fine-structure constant, α. This quasar was observed for 16.1 h with the Very Large Telescope and the new ESPRESSO spectrograph. This culminated in the first ESPRESSO constraint on relative variations in α with parts-per-million precision, $\Delta\alpha/\alpha = 1.3 \pm 1.3_{stat} \pm 0.4_{stat}$. The high resolving power of the ESPRESSO spectrum enabled the identification of very narrow

components within the absorption profile allowing a more robust analysis of Δα/α. These results are presented in the paper “Fundamental physics with ESPRESSO: Precise limit on variations in the fine-structure constant towards the bright quasar HE 0515-4414” (Murphy et al. to be published in A&A), with several team members as authors.

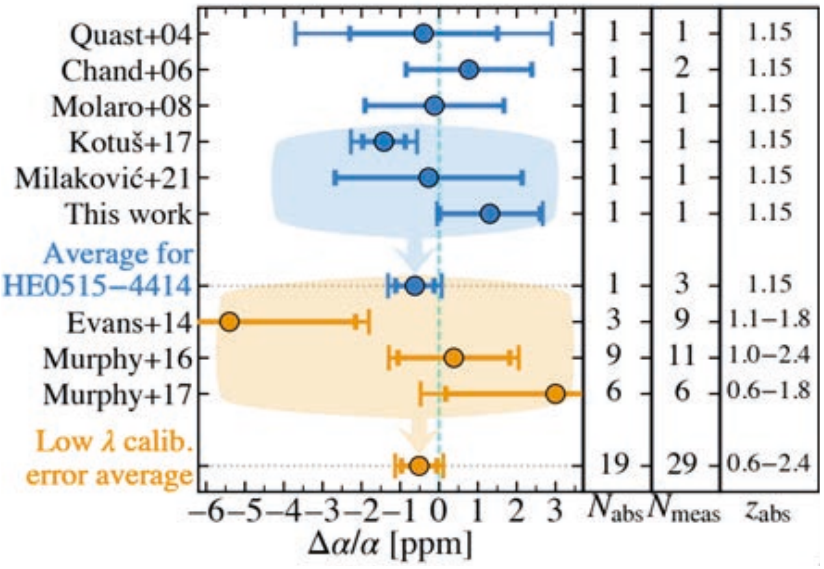


Figure 1: Measurements of the fine structure constant variation in the z=1.1508 absorber towards HE0515-4414 (blue points) and recent measurements corrected (or insensitive) to wavelength calibration errors (orange points).

2. Euclid preparation papers

The first Euclid pre-launch key paper, “Euclid preparation: I. The Euclid Survey” is ready to be published in A&A, with several team members as core authors. This paper presents the building of the Euclid reference survey: the sequence of pointings of the Euclid Wide Survey, Deep fields, Auxiliary fields for calibrations and spacecraft movements followed by Euclid as it operates in a step-and-stare mode from its orbit around the Lagrange point L2.The resulting reference survey fulfils all constraints and is a good proxy for the final solution. Its wide survey covers 14,500 square degrees.

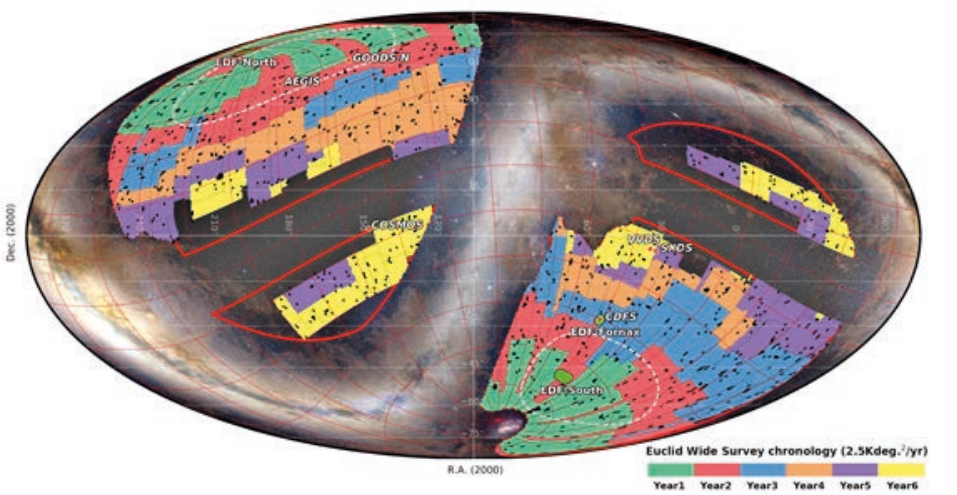


Figure 2: Reference Survey Definition 2021A (14514 square degrees) chronology shown in celestial coordinates. Region-of-interest boundaries are shown as solid red lines. The three Euclid Deep fields (bright green) and the six Euclid Auxiliary fields (red diamonds, not in size) are shown.

3. **Putting modified gravity to the test**

   The correct gravitational theory explaining the presently observed cosmic acceleration is still an open question. Several alternative gravitational theories are still viable candidates, and this is research that is actively being worked on by several team members. One particular model is f(Q) gravity, where gravity is described by the nonmetricity scalar Q rather than the Ricci scalar. This description can actually be equivalent to General Relativity for the simplest case where the action is given by Q. Interestingly, certain forms of f(Q) give rise to a universe where the background evolution is identical to a standard ΛCDM model, though differences arise at the perturbative level. In the paper "Signatures of f(Q)-gravity in cosmology" by team member Frusciante, published in PRD, the effects of this model on the matter power spectrum and on the cosmic microwave background radiation angular power spectrum was investigated. It was found that these models can either suppress or enhance these spectra, depending on the values taken by its single parameter. The paper also looks at possible constraints on this model coming from standard siren observations from future gravitational waves detectors.

4. **Conclusion of the CANTATA Network**

   The European COST Network "CANTATA" had significant input from several members of the team from its design and proposal through to its end in 2020. This year the research carried out within CANTATA has been compiled in a book, published in Springer, "Modified Gravity and Cosmology", Saridakis et al. This book provides a comprehensive review of theories of modified gravity, detailing the observational consistency of individual theories. Several team members are co-authors in this work.

Group meetings, Journal Clubs and other activities

The cosmology group held almost ten seminars during 2021. These were mostly online zoom seminars due to the current pandemic situation.

The group also had regular weekly journal club meetings. In total the group held 37 "CosmoClub" online zoom meetings in 2021. Every week a different team member brings one paper (sometimes more) for discussion. Details can be found in http://ia-cosmoclub.wikidot.com

Team members were also actively engaged throughout 2021 with the Science Communication group for several outreach activities.

Three students of the cosmology team successfully completed their PhD thesis in 2021.

Tiago Barreiro
Group Leader

Report from the Group

Astronomical Instrumentation and Systems

Due to the pandemic situation that continues to affect everyone, 2021 was again a very hard year for the Astronomical Instrumentation and Systems Group (AISG). The observatories were closed, all the work was done remotely and the delivery times of parts and manufacturing services became much longer than normal. Nevertheless, as seen in this report, we were able to progress significantly in the current running projects and prepare the ones to come in the next year.

During 2021, the following instruments had engineering and implementation activities at IA:

- For the European Southern Observatory (ESO): NIRPS, MOONS and HIRES
- For the European Space Agency (ESA): EUCLID, CHEOPS, PLATO, ARIEL and ATHENA.

Currently the AISG participates in a considerable number of projects, involving all its human resources. This includes not only the technical design of the instruments themselves but also the respective science exploration of the collected data through big collaboration projects such as consortiums and surveys. Its importance stems from the need to secure privileged access to existing and future facilities of the European Organization for Astronomical Research in the Southern Hemisphere (ESO) and of the European Space Agency (ESA) and to contribute to the long term development of Astronomy in Portugal.
During 2021, Bachar Wehbe concluded his PhD thesis, titled *"Atmospheric Dispersion Correction for High Resolution Astronomical Instruments"* and also became a researcher of IA.
Two new PhD students started their work at the end of the year: Inês Leite and Nuno Gonçalves.

In terms of new themes of research, somehow supported by background expertise in Astronomy Instruments / Space missions, are consolidated by the work of two running and two newcomer PhD students supervised by AISG researchers:

a. Stabilisation of calibration light sources for High Accuracy Photometry Instruments resulting from research and develop a device that senses the light source fluctuations and modulates the beam, both in flux and in spectra, to produce a sufficiently stable source, a truly impressive challenge when stabilisation levels of few ppm are required over long periods of observation.

b. Discovery and characterization of temperate Earth-like worlds with ESPRESSO, with a main goal to improve the radial velocity extraction from the ESPRESSO science data. This is a module to be attached to the Data reduction pipeline of ESPRESSO. This thesis is more focused on the analysis of M stars which are trickier to get precise and stable radial velocities for the detection of exoplanets, but at the same time are the more promising targets to find earth-like in the habitable zone.

c. Development of a solar telescope that will allow the detailed study of the Sun (using it as a proxy to understand the sources of noise that affect the observations of other stars). For that, it is fundamental to be able to obtain disk-resolved HR spectra, opening a whole new path for the detection and characterization of Earth-like planets orbiting other Suns.

d. Development of miniaturised Cross dispersed echelle spectrographs operating in the VIS and UV with the Size Weight and Power (SWaP) requirements for a SmallSat solution and the required spectral resolution to allow the study of this less explored spectral range.

Following is listed the activity detail of the running projects.

1. **NIRPS (ESO)**

NIRPS is a new (fast-track instrument) high resolution spectrograph working at near-infrared bands, that is being designed for the ESO 3.6-m telescope (La Silla-Paranal Observatory). NIRPS will work together with the existing HARPS spectrograph, allowing us to obtain simultaneous optical and near-IR spectra of stars. The major goal of NIRPS is to detect and characterise planets orbiting late type stars. The NIRPS consortium includes a strong participation from IA, including in the development of hardware and software (the Atmospheric Dispersion Correctors - ADC), and in the definition of scientific activities.
2021 saw the conclusion of the commissioning of the ADC in the ESO 3.6 m telescope in La Silla. Due to the confinement, all the activities were done remotely, increasing the complexity and time required to achieve the success. First light for science is foreseen in 2022.

2. **MOONS (ESO)**

The Multi-Object Optical and Near-infrared Spectrograph (MOONS) is a future third-generation instrument for the Very Large Telescope (VLT) to have first light by 2023. It matches an enormous multiplexing capability, reaching up to 1000 positions being spectroscopically observed at the same time over a single telescope pointing to the grasp of the 8.2m VLT, making it a unique instrument for deep galaxy surveys.
The subsystems under IA responsibility are the MOONS Rotating Front End (RFE) and the Field Corrector (1 m diameter set of two lenses). In 2021 the activities focused on the conclusion of the tests of all the mechanisms that the RFE will comprise and also in the integration of a new metrology system that the team was in charge of. It is now expected that the fully integrated RFE is transferred during the first half of 2022 to UKATC in Edinburgh for Preliminary tests in Europe before its integration in Chile. The field corrector manufacturing was concluded (and systems were accepted) and the structure that will interface it with the telescope started its manufacturing in 2021 (to be concluded in the beginning of 2022).

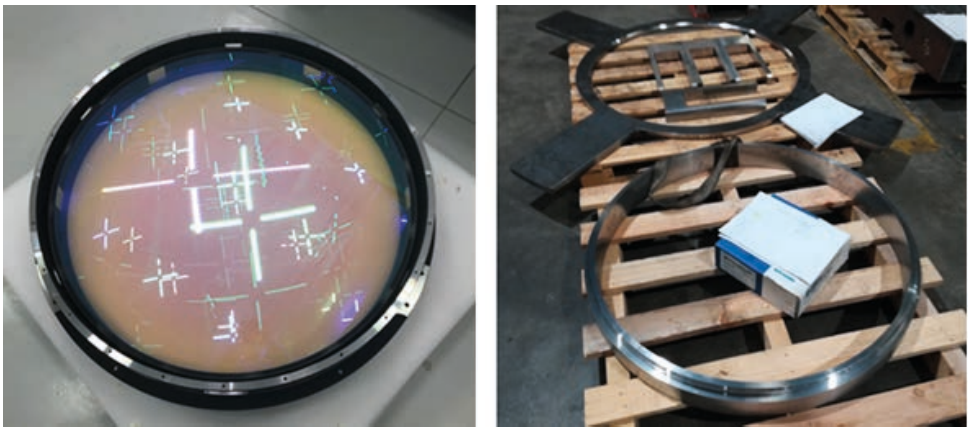


Figure: The MOONS (ESO) FC lenses at Officina Stellare (Italy) and the current status of the structure that will support it in CUNHOL (Portugal).

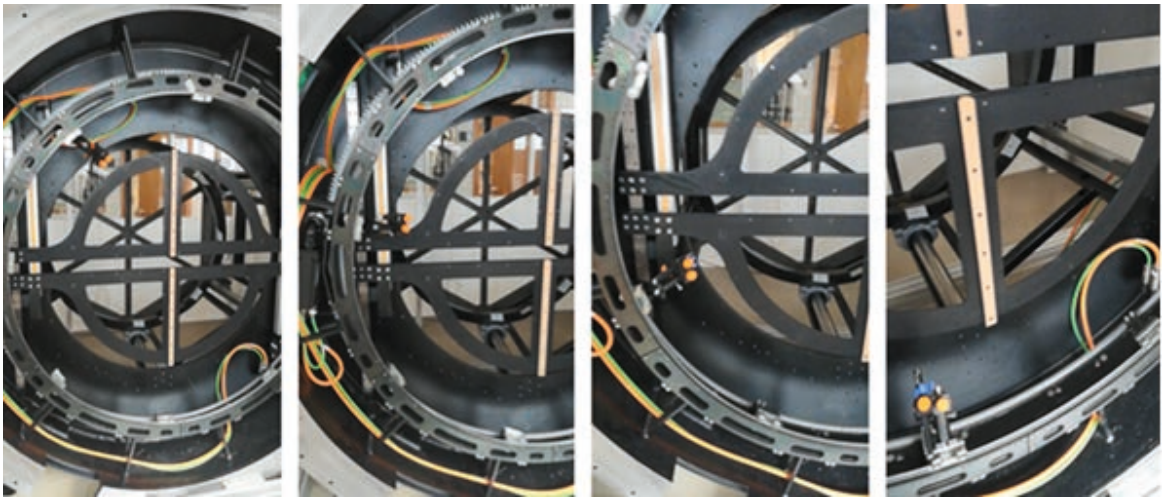


Figure: The MOONS (ESO) RFE during integration on the new rotation metrology subsystem.

3. HIRES (ESO)

HIRES is the project for a high resolution spectrograph to be installed at the ESO E-ELT telescope. The concept of HIRES is being developed by a consortium that comprises several institutes in different European countries, as well as USA, Canada, Brazil and Chile. The Portuguese participation in this consortium is done through IA that is leading the “front end” workpackage component of the instrument, the data reduction and analysis software, the software system architecture, and the science drivers for the project. The group also participates in the management of the consortium, having several key persons.
After the finishing of the Phase A studies in 2017, during 2021 the work was focused on the Pre-phase B activities, namely on the consortium definition, on the preliminary re-design of the instrument, on the consolidation of cost estimates, on the consolidation of science cases and plans for GTO program. In the final days of 2021 the Instrument got the green light from ESO to start. Phase B is foreseen to Kick off March 2022.

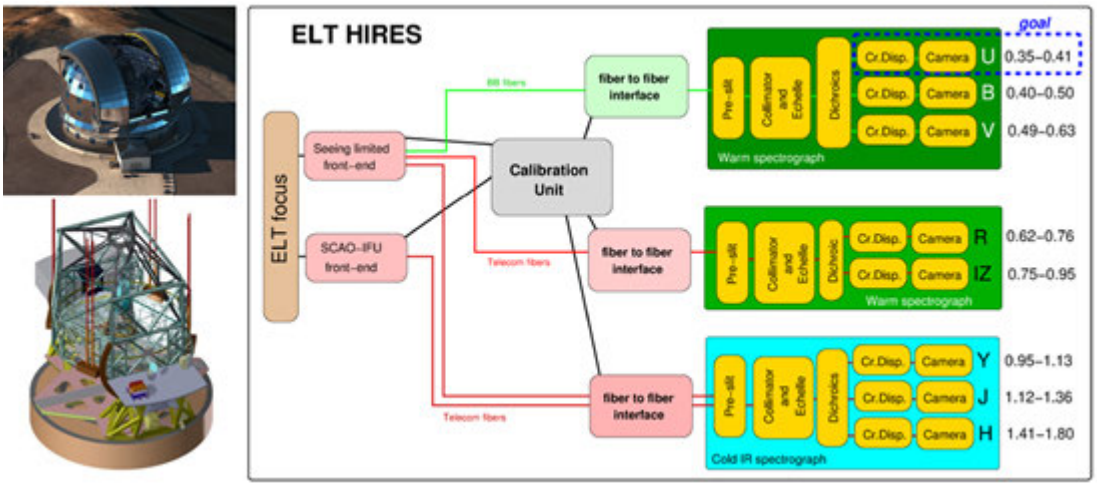


Figure: HIRES (ESO) at the ELT and instrument architectural design, outlining the instrument subsystems: Front End (seeing-limited and AO assisted with SCAO unit), Fibre Link, Calibration Unit, VIS-Blue, VIS-Red and NIR (cold spectrograph).

4. EUCLID (ESA)

Euclid is ESA's mission dedicated to the exploration of the dark universe through the measurement of the properties of the cosmological large-scale structure. IA is strongly involved in this mission, participating in the consortium board, in various science working groups, and in the Survey Design, which is an activity of support to the Euclid Consortium Lead.

In 2021, IA's Instrumentation and Systems Group continued its long standing participation in the preparation of the Survey Design, focusing on the development of the ECTile software. This software computes the mission's Reference Survey, i.e., it produces schedules of the Euclid Deep and Wide surveys, including implementation of all calibrations, compliant with all constraints and requirements. This year further consolidated the development of the survey generating tool.

The major novelty was the introduction of a scheme to avoid observing very bright stars. At first, this was implemented by skipping tiles of a tessellation. Later, this was further improved by adapting the tessellation to snug tightly around bright stars. This also required the adaptations of the patch scheduling, to skip across the holes left behind by bright stars.

Another source of attention was the injection of the SOP (special operations) windows. These are spacecraft maintenance slots that need to take place exactly once every four weeks (around noon, on Mondays). It had a major impact on development, given its stringent requirements and the coupling with the PSF calibrations (another stringent target). The inner workings of the tool were also improved with the implementation of a new framework for designing the intermediate survey; a mid-stage survey made of only calibrations and deep-fields.

A few smaller activities also took place. The covering of deep-field south shape, a stadium, was improved with a tighter set of patterns. The instruments FoV (VIS and NISP) were measured as build, requiring an adaptation to its precise contours, with impact on the tessellation. The range of alpha and solar aspect angles (that strongly conditions the movements of the spacecraft) was reduced slightly, requiring some adaptations to the surrounding algorithms. In total, three reference surveys were delivered this year. The first, the RSD2021A, was delivered in July. A second survey was delivered in September, the RSD2021B, for the SVT-1 validity review (by ESA). A third survey was delivered, the RSD2021C that fixed some inconsistencies spotted in the review.

The year ended with the development of an additional four surveys, one to incorporate all the latest specifications and corrections, and three more to test a few scenarios, all to be delivered in time for the Mission Keypoint Review, to be held in January 2022.

In 2021 we also participated as leading authors in writing the first Euclid key paper; Euclid preparation: I. The Euclid Wide Survey (in press, A&A accepted, arXiv preprint: https://arxiv.org/abs/2108.01201)

As launch approaches, a more intensive calendar of survey meetings was put in place by ESA. The group was present in these new regular bi-weekly meetings with ESA.

5. CHEOPS (ESA)

The Characterising Exoplanet Satellite (CHEOPS) is the first mission dedicated to search for transits of exoplanets by means of ultrahigh precision photometry on bright stars already known to host planets. It will provide the unique capability of determining accurate radii for a subset of those planets for which the mass has already been estimated from ground-based spectroscopic surveys. CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterization of exoplanetary atmospheres. IA is strongly contributing for this mission participating both in the board and the core science team of the mission. This work is also closely related with the science data archive which is being developed by our industry partners (DEIMOS), contributing to the development of stronger relations with the Portuguese industry in the area of scientific related software.

Moreover there is a contribution for the mission science operation centre, more specifically for the CHEOPS data reduction pipeline where we are responsible for the calibration of the pipeline.

In 2021, CHEOPS will continue to run well within specifications and continue to get scientific observations of high precision. IA continues to give maintenance support to the data reduction pipeline during the CHEOPS mission. In the final trimester of 2021, the CHEOPS consortium has started discussion for the possibility of an extension to the mission and this will be proposed in 2022.

6. PLATO (ESA)

The PLATO mission, whose main scientific focus is the detection and characterization of extra-solar planets orbiting nearby, bright stars, using the transit method, as well as the detailed characterization of their host stars through asteroseismology, was adopted by ESA in June 2017. The instrumentation team has leadership of several work packages for the development of software for the Plato Data Center (PDC) as well as in the development of the Optical Ground Segment (OGSE) component to test and calibrate the PLATO cameras on ground.

Regarding the contribution to the OGSE, since the beginning of 2021, the collimator built by IA was integrated in the CSL (Be) setup and is contributing to the process of integration and test of the Plato cameras. The IA team has been supporting CSL in the operation of the collimator, in particular adapting/configuring the collimator software to meet the specifications of Electronic GSE built by the Belgium team.

During 2021, a second collimator was also mounted and prepared to be shipped to CSL Belgium in the beginning of 2022.

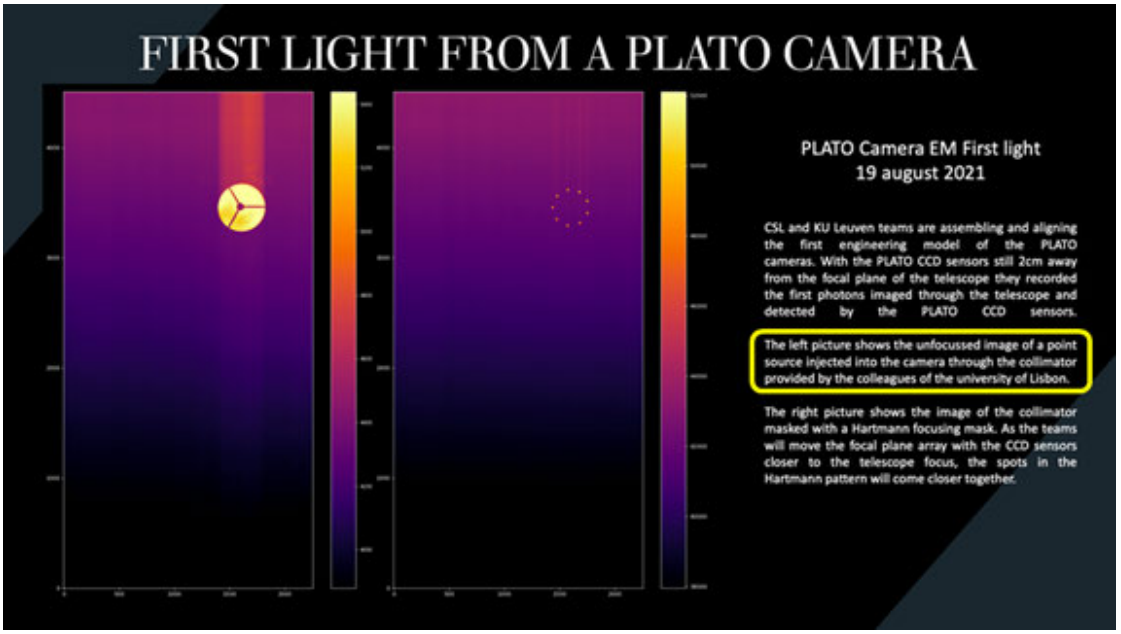


Figure: PLATO (ESA) Fist light from Plato camera using the White light collimator built by IA.

The activities regarding other work packages associated with instrumentation, namely with SW work, in Star Centroids and Target Position, our team continued to produce documentation and supporting algorithms, in the scope of the activities led by LESIA group.

7. ARIEL (ESA)

ARIEL (Atmospheric Remote-sensing Exoplanet Large-survey) was one of the three candidate missions selected by the European Space Agency (ESA) for its next medium-class science mission due for launch in 2028. The goal of the ARIEL mission is to investigate the atmospheres of several hundred planets orbiting distant stars in order to address the fundamental questions on how planetary systems form and evolve.

The main activities of IA – instrumentation in ARIEL and together with the OGSE team led by Oxford University, were associated with the definition of the OGSE requirements.

The main effort of the team resulted in the SRR milestone being achieved successfully in the first months of 2021.

Since then, work progressed to the completion of the next milestone, the PDR, which will occur in February 2022.

The contribution of IA in the OGSE will include the development of the Visible and Near IR illumination unit, as well as in the development of a reference detector to monitor source intensity fluctuations. Regarding this last issue, the team is preparing a cryo/vacuum setup to test the reference detectors in a 70K environment.

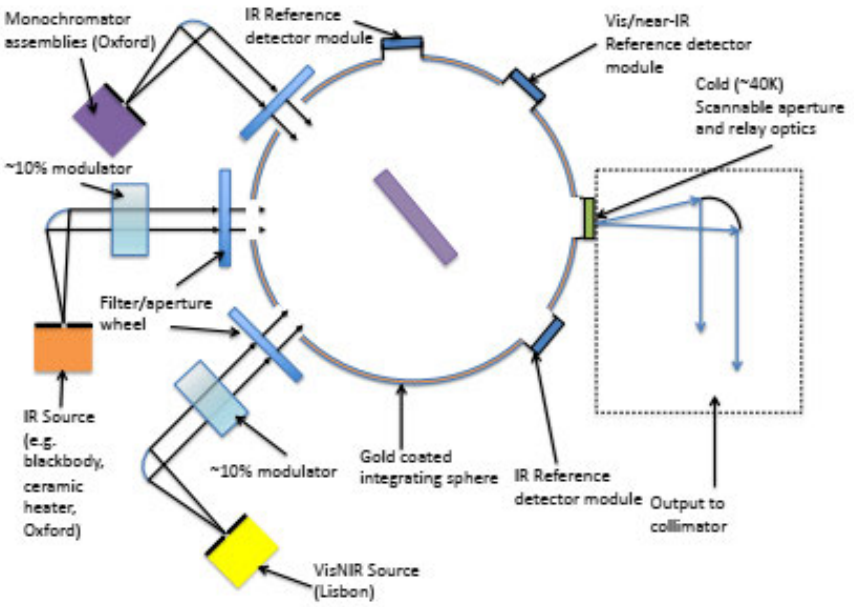


Figure: Schematics of the light source of the Ariel OGSE, which will integrate the VisNir source and the VisNIR reference detectors.

8. ATHENA (ESA)

The group of Instrumentation of IA is leading the international consortium for the development of the Athena mission on-board metrology system, in the sequence of the approval of activity proposal to the ESA tender, which had the kick off in June 2020.

The function of the system being developed by the team is measuring the exact pointing of the Athena mirror during the process of switching focus between the X-IFU and WFI Athena instruments. The level of accuracy required for this task is at the level of a fraction of an arcsecond.

During the year of 2021 the team successfully achieved the SRR milestone and is now on course for the PDR, which will occur in the beginning of 2022.

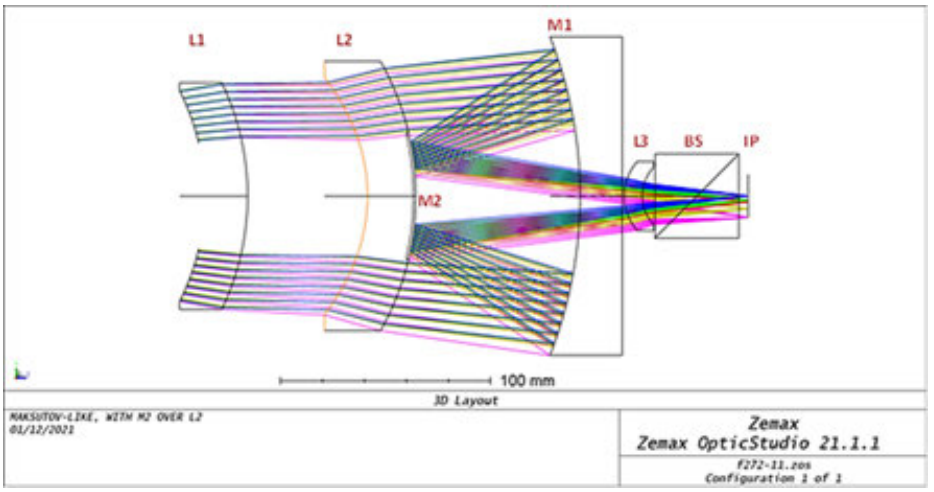


Figure: Depiction of the optical telescope being developed for the Athena OBM.

Highlights for 2021

1. The conclusion and acceptance of the MOONS field corrector, comprising two lenses with 900 mm diameter for the ESO Very Large Telescope.
2. The successful commission on the sky of the NIRPS ADC in the 3.6m telescope of the La Silla ESO observatory.
3. First light of a Plato Camera using our collimator. Second collimator being finalised for delivery to CSL
4. ARIEL OGSE System requirements review: successful milestone
5. Athena OBM System requirements review: successful milestone
6. HIRES green light to go from the European Southern Observatory.

Alexandre Cabral
Group Leader

Report from the Group

Science Communication

Like the previous year, 2021 was also marked by the COVID-19 Pandemic. Schools closed on January 22 and only gradually reopened as of March 15. Many public events were cancelled and all cultural venues were forced to reduce their capacity. The impact of the pandemic at IA Science Communication Group (SCG) activity was even more severe than the previous year.

During 2021 the SCG organised and participated in several public outreach initiatives which reached a total of more than **32 012** (24,659 @2020) **people (in person)**. This number corresponds to **an increase of 30%** in relation to the previous year, even with the pandemic forcing the cancellation of most in person public events. On the other hand, with an intense investment on online activities, the SCG was able to obtain 13 595 (**46,504 @2020) views, a decrease** due to the saturation of viewers about online events. The number of followers in IA social networks had a slight increase, but the general activity decreased.

The number of Facebook followers increased 4,4% for 8812, Twitter got 75 new followers, Instagram followers had an increase of 59,6%(+ 327), and youtube got an increase of 22,3% of new subscribers (+ 390).

During 2021, IA produced 301 regular (unpaid) **Facebook** posts (-17.1% decrease over 2020) with a total reach through regular (unpaid) posts of 235 642 unique users, which corresponds to a 22% decrease over the unpaid reach in 2020.The reach through the two paid posts (partnership with Science Office online training), was 400 320. This was a 27.6% increase over the paid reach in the same previous period. In **Twitter**, IA produced 282 tweets (6.3% decrease over the previous year), got 84 070 views (9.8% decrease over the previous period), and 323 mentions. In **Instagram**, during 2021, IA produced 196 publications, an increase of 76.6% over 2020 (111). IA publications on Instagram reached 48 923 instagram users. IA's channel on **YouTube**, in 2021, got 13 161 views.

This was a 39.1% decrease relative to the previous period.

Public activities directly organised by IA reached about **12 963 people** in person and **6 410 online views**, including, among others, planetarium shows, monthly periodic outreach sessions, exhibitions, showcases, hands-on laboratories and special public events and talks. The impact of the pandemic on Planetarium activity was worse in 2021 than in the previous year. Although the general public shows for several times sold out, school visits were very low.The SCG team has also participated in several initiatives promoted by other institutions, such as Ciência Viva, the Museums of the University of Lisbon and many schools, contributing also with talks, observations of the night sky, planetarium shows, exhibitions, showcases, workshops and short courses,

having reached about **18 937 people** in person and **7 185 online views**.

The SCG has been responsible for the creation of the “ESPRESSO exoplanet portal” website which incorporates several educational contents, the first stage was finished and launched in 2021. It includes six interactive infographics where users can explore and learn about the known stars and exoplanets, already detected and/or being studied with data from the ESPRESSO spectrograph. Users can learn about the detection methods of exoplanets (radial velocities, transits, astrometry and gravitational lensing), and the concept of the habitable zone of a star.


NATIONAL GEOGRAPHIC

CIÊNCIA HISTÓRIA ANIMAIS VIAGEM E AVENTURAS MEIO AMBIENTE

ESPAÇO

Como forjar as mais deslumbrantes fornalhas da Via Láctea?

Imaginemos várias dezenas de sóis compactados numa única estrela. A tremenda explosão final de uma estrela tão grande é sentida através da galáxia até bem longe. Felizmente, estrelas destas são raras, e o motivo reside no seu local de nascença.

POR NANDA KUMAR
PUBLICADO 1/10/2021, 11:02

Imagem obtida com o telescópio espacial Hubble que mostra a região compacta de formação estelar Sh 2-106, na constelação do Cisne. A estrela recém formada no meio da poeira no centro da imagem é responsável pela forma e pela turbulência visíveis na nuvem de gás circundante.

FOTOGRAFIA DE NASA & ESA

The SCG continued its partnerships with National Geographic Portugal and SAPO Tek websites, for the production of articles for the public. This increases the visibility of IA since, for example, SAPO Tek reaches about 2 million people. In 2021 the SCG produced **8 articles** for National Geographic and 4 for SAPO Tek. The SCG also created several media contents, such as **17 videos** (Youtube), and contents for its official webpage.

IA has an ongoing partnership with the Leiden Observatory/ University of Leiden for the development of an Astronomy Literacy Project. This international joint-project aims to define global astronomy education goals to be applied in worldwide school curricula. Another goal of this project is the production of localised astronomy educational contents in several languages, together with educational guidelines for educators. “**Big Ideas in Astronomy: A Proposed Definition of Astronomy Literacy**”, the first global Astronomy Literacy document, was the first outcome of the Astronomy Literacy project, led by IA and the Leiden University. The second version of this document was announced by the International Astronomical Union (IAU) on the 5th October 2021. It has been released as a booklet in seven languages, including Portuguese, and made globally available on a dedicated website. IA’s Science Communication Group produced the Portuguese translation and also the development of a new complete website, launched in October 2021 by the International Astronomical Union’s Office of Astronomy Education (OAE).

The SCG team produced and made available to the media **18 press releases** (16 national, 2 international) related to the science produced by IA or to its outreach activities. This number of press releases resulted in about **447** references in national news media with a total Automatic Advertisement

Value (AAV) of about **€ 7 143 651,40.** We also made available through our webpage and partners, **6 news releases**.

IA has been mentioned by international news media, for example: Der Standard, Space.com, The Galaxy Daily, Swiss Info (SWI) and Sorae (Japan).

The science communication and education work at IA has been presented in national and international conferences with invited and contributed talks and workshops – 7 invited talks, 2 invited workshops and 10 contributed talks. The conferences include, among others, the CAP Conference: Communicating Astronomy with the Public 2021, the 9º Congresso SciComPt and the 31º Encontro Nacional de Astronomia e Astrofísica. The team published one Master's dissertation and is responsible for several articles for monthly columns.

The SCG has co-supervised the dissertation project of 1 students from Mestrado em Comunicação de Ciência from the Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa, 2 undergraduate students for a 3-month internship from Faculdade de Belas Artes da Universidade do Porto, 3 undergraduate students for three months internships in digital animation for science education from Universidade Lusófona, 1 students from a two month internship from Escola Artística e Profissional Árvore, 2 students developed a 3D visualisation and mapping application of the stars with extrasolar planets from Instituto do Emprego e Formação Profissional, and for the first time 3 groups of students from the post-graduate course of the Master of Imaging from Faculdade de Engenharia da Universidade do Porto.

Summer Internships: IA organised online summer internships in all IA's 6 areas of work, including Science Communication. During three weeks, six students attended the internship in Science Communication promoted by IA (Inês Machado, Kelly Matsui, Iara Tiago, Inês Heitor, Mafalda Silva and Ana Carina Costa) in which they developed the final project "Fora da caixa: como motivar para a ciência?".

During 2021, the SCG has conducted several training sessions for teachers, science communication officers, students and the general public.

The SCG is responsible for the creation and development of several national projects like Ler+Espaço, Tour Ignite IAstro (suspended in 2021) or the IAstro Júnior (suspended in 2021) . IA also participated in the Cientificamente Provável (suspended in 2021) programme, a partnership by the Portuguese Government, implemented through the network of school libraries, and in the Clubes Ciência Viva na Escola, a Ciência Viva project, partnering with 71 schools.

IA provides the scientific management of the Planetário do Porto CCV activities, all of which are developed, organised and implemented by members of IA's SCG, having reached in 2021 **16 383 people** through fixed domed and portable planetarium sessions, hands-on

laboratories and online activities.

IA continues with a strong involvement with the “Portuguese Language Expertise Centre for the Office of Astronomy for Development (of the International Astronomical Union)” - PLOAD. It is hosted by Núcleo Interativo de Astronomia (NUCLIO), in collaboration with IA. The PLOAD’s main objectives are to establish a strong collaborative network between Portuguese speaking countries and communities and empower these countries and communities with the necessary tools to build their own local support structures and strategy development in Astronomy and Space Sciences.

PLOAD
Grupo Lusófono de **Astronomia** para o Desenvolvimento

The strategy of the SCG for the 2021-2022 period envisions to continue implementing public engagement activities with students of the various school levels in particular, and the production of Astronomy related educational and science communication contents for several specific target audiences, with a special focus on students and teachers. This production will be strengthened by the involvement in the “Astronomy Literacy” international project. These contents can exist by themselves or be produced with specific uses such as planetarium sessions, hands-on activities or exhibitions. In this context, the management of the Planetario do Porto is essential to project the IA to society and provide human resources for the groupThe production of these materials will place IA as the main institution in Portugal in terms of the production of Astronomy related contents. IA’s strong involvement in the PLOAD will allow the dissemination of its contents throughout the Portuguese language countries which engulfs 240 million people, giving to the IA’s Science Communication a real international dimension.

João Retrê and Filipe Pires
Group Leaders

Scientific Output

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45. **J. R. C. C. C. Correia**, **C. J. A. P. Martins**; 2021; *High resolution calibration of string modelling*; COSMO'21 Conference, Online, Estados Unidos da América
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54. **M. Deal**; 2021; *Transport of chemical elements in main-sequence stars*; PLATO Mission Conference 2021, Online
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62. **J. D. F. Dias**, **P. Machado**, J. L. F. Ribeiro; 2021; *Detection and limits of detection of minor chemical species in Solar System's atmospheres*; EANA 2021 Conference, Online
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74. **J. Gomes da Silva**; 2021; *The relationship between activity and age in late-type stars*; PLATO HOW#2: Uncertainties in stellar properties determination, Online
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78. **M. S. N. Kumar**; 2021; *Filaments,Hubs, Coalescence and Cluster Formation*; ISM 2021 Conference, Online, Líbano
79. **I. M. Leite**, **A. Cabral**; 2021; *Instrumentation for spacially resolved solar spectroscopy*; 7th NYRIA workshop, Online
80. **C. Leote**, **S. Pereira**, B. D. Fields; 2021; *Posters and slides: how to prepare and present them?*; Network of Young Researchers in Instrumentation for Astronomy - Workshop 2021, Online
81. **C. Leote**, **S. Pereira**, **J. Retrê**, **P. Machado**, **G. Gilli**, **J. Silva**, **R. Gonçalves**, **P. I. T. K. Sarmento**, **A. Cardesín-Moinelo**; 2021; *Assembling aliens to explore the Solar System*; EPSC2021, Online
82. **C. Leote**, **S. Pereira**, **J. Retrê**, **P. Machado**, **G. Gilli**, **J. Silva**, **R. Gonçalves**, **P. I. T. K. Sarmento**, **A. Cardesín-Moinelo**; 2021; *A board game about the Solar System in times of a pandemic*; CAP Conference: Communicating Astronomy with the Public 2021, Online
83. **R. Lima**; 2021; *Um céu 5 estrelas vs. 5 estrelas no céu*; XXIV CEA - Congreso Estatal de Astronomía, Corunha, Espanha
84. **R. Lima**; 2021; *Overview of light pollution: the environment, public health and some more bright and dark sky subjects*; International Astrotourism Conference by Starlight, Évora, Portugal
85. **F. S. N. Lobo**; 2021; *Beyond Einstein's General Relativity: Hybrid metric-Palatini gravity*; International Webinar on Recent Developments in Cosmology and Modified Gravity, Pilani, Índia
86. **F. S. N. Lobo**; 2021; *Beyond Einstein's General Relativity: Hybrid metric-Palatini gravity*; GRAVITEX 202, Online, África do Sul
87. **F. S. N. Lobo**; 2021; *Curvature-Matter Couplings in Modified Gravity*; 4th PU Int. Conference on Gravitation and Cosmology, Online, Pakistan
88. **P. Machado**, **F. Brasil**, **G. Gilli**, J. Silva, **D. C. Espadinha**, A. Cardesín-Moinelo, B. Gondet; 2021; *Mars wind maps and gravity wave characterisation using Ground Telescopes and Mars Express and Trace Gas Orbiter observations*; The 14th Sci Science Workshop, Aranjuez, Espanha
89. **P. Machado**, A. Cardesín-Moinelo, **G. Gilli**, **F. Brasil**, **J. Silva**; 2021; *Final Results of Doppler Velocimetry Winds on Mars' Atmosphere*; EPSC2021, Online
90. **C. J. A. P. Martins**; 2021; *Testing the Universality of Physical Laws at the BBN Epoch*; ESO Cosmic Duologues, Online
91. **C. J. A. P. Martins**; 2021; *BBN with GUTs*; XV Iberian Cosmology Meeting, Online, Portugal
92. **C. J. A. P. Martins**; 2021; *ELT: How to Prepare a Revolution*; PLANCKS 2021 Meeting, Online, Portugal
93. **C. J. A. P. Martins**; 2021; *Coding the Cosmos: A New Generation of Superstring Simulations*; EuroHPC Summit Week 2021, Online
94. **C. J. A. P. Martins**; 2021; *Recent Fundamental Physics Theoretical Developments*; ESPRESSO Science Team Workshop, Online
95. **C. J. A. P. Martins**; 2021; *Astrophysical spectroscopy tests of the Einstein Equivalence Principle: the ESPRESSO era*; Second EPS Conference on Gravitation: measuring gravity, Online, Reino Unido
96. **C. J. A. P. Martins**; 2021; *Varying fundamental constants and dark energy in the ESPRESSO era*; 16th Marcel Grossmann Meeting, Online, Itália
97. **C. J. A. P. Martins**; 2021; *Alternatives to Lambda: Torsion, Generalized Couplings, and Scale Invariance*; 16th Marcel Grossmann Meeting, Online, Itália
98. **C. J. A. P. Martins**; 2021; *Observational constraints on nonlinear matter extensions of general relativity*; 16th Marcel Grossmann Meeting, Online, Itália
99. **C. J. A. P. Martins**; 2021; *Closing the cosmological loop with the redshift drift*; 16th Marcel Grossmann Meeting, Online, Itália
100. **C. J. A. P. Martins**; 2021; *Teaching Relativity at the AstroCamp*; 16th Marcel Grossmann Meeting, Online, Itália
101. **C. J. A. P. Martins**; 2021; *Primordial nucleosynthesis with varying fundamental constants: Improved constraints and a possible solution to the Lithium problem*; COSMO'21 Conference, Online, Estados Unidos da América
102. **J. P. Mimoso**, A. Maciel, **M. Le Delliou**; 2021; *Tolman-Oppenheimer-Volkoff conditions beyond spherical symmetry*; 16th Marcel Grossmann Meeting, Online, Itália
103. **N. A. M. Moedas**; 2021; *Investigating the chemical evolution in solar-like stars: Effect of turbulent mixing in*

stellar models; 8th Iberian Meeting on Asteroseismology, Porto, Portugal

104. **A. L. Morozova**, **T. Barata**, T. Barlyaeva; 2021; *PCA-MRM model for TEC over the Iberian Peninsula: performance in different space weather conditions*; IAGA-IASPEI 2021, Online
105. **A. L. Morozova**, **T. Barata**, T. Barlyaeva; 2021; *Space weather parameters as predictors in the TEC models*; 17th European Space Weather Week 2021 (ESWW 2021), Glasgow, Reino Unido
106. **A. L. Morozova**, **T. Barata**, T. Barlyaeva; 2021; *Comparison of the performance of PCA-NN and PCA-MRM models for TEC over the Iberian Peninsula*; AGU Fall Meeting 2021, Online, Estados Unidos da América
107. **A. L. Morozova**, T. Barlyaeva, **T. Barata**; 2021; *Modeling of TEC over the Iberian Peninsula using PCA decomposition and multiple linear regression on space weather parameters*; EGU General Assembly 2021, Online
108. **A. L. Morozova**, **T. Barata**, T. Barlyaeva; 2021; *Space weather parameters as predictors in TEC models*; 17th European Space Weather Week 2021 (ESWW 2021), Online
109. **A. L. Morozova**, **T. Barata**, T. Barlyaeva, H. -J. Gerber; 2021; *PCA-MRM model for TEC over the Iberian Peninsula: performance in different space weather conditions*; IAGA-IASPEI 2021, Online, Índia
110. **C. Pappalardo**; 2021; *The Promise of Radio Astronomy*; 6th East African Astronomical Society Workshop, Dodoma, Tanzania
111. **C. Pappalardo**; 2021; *Self-consistent population spectral synthesis with FADO: mean stellar metallicity of galaxies in spectral synthesis method*; Chemical Abundances in Gaseous Nebulae - UniVap, Online, Brasil
112. **A. Paulino-Afonso**; 2021; *Artificial redshifting and host mass bias*; CRISP meeting, Peniche, Portugal
113. **S. Pereira**, A. Alves, **C. Leote**, **J. Retrê**; 2021; *An astronomy research show is touring remote locations*; CAP Conference: Communicating Astronomy with the Public 2021, Online
114. **R. Rebbaha**, **A. L. Morozova**; 2021; *Study of the regular daily variations of the geomagnetic field Sq and SD obtained from the Coimbra Magnetic Observatory (COI) observations by different methods compared to the comprehensive Model CM5 of the quiet-time*; IAGA-IASPEI 2021, Online
115. **J. L. F. Ribeiro**, **P. Machado**, S. Perez-Hoyos, P. G. J. Irwin; 2021; *A reanalysis of ISO-SWS Jupiter observations: first results*; EPSC2021, Online, Espanha
116. **J. Rodrigues**, **S. C. C. Barros**, **N. C. Santos**; 2021; *FULMAR: Follow-Up Lightcurves Multitool Assisting Radial velocities*; Tess Science Conference II, Online
117. **J. Rodrigues**, **S. C. C. Barros**, **N. C. Santos**; 2021; *Follow-Up Lightcurves Multitool Assisting Radial velocities (FULMAR)*; Europlanet Science Congress 2021, Online
118. **N. M. Rosario**, **S. C. C. Barros**, **O. Demangeon**, **N. C. Santos**, **B. Akinsanmi**; 2021; *Measure the spin-up of hot Jupiters due to tides*; TESS Science Conference II, Online, Estados Unidos da América
119. **I. Yu. Rybak**; 2021; *Dynamics and Y-junctions of superconducting (transonic) cosmic strings*; IberiCOS 2021, Coimbra, Portugal
120. **N. C. Santos**; 2021; *A solar telescope for planet hunters*; The Star-Planet Connection, Online
121. **N. C. Santos**; 2021; *Finding the lowest mass planets with ESPRESSO*; EANA 2021 Conference, Online
122. **N. C. Santos**; 2021; *PoET: a solar telescope for planet hunters*; NASA ExoPAG Study Analysis Group (SAG) 21 Community Symposium, Online
123. **N. C. Santos**; 2021; *A compositional link between rocky exoplanets and their host stars*; ESO Workshop The Star-Planet Connection, Online
124. **N. C. Santos**; 2021; *Exoplanet Science: from ground to space*; Workshop Sciences and Technologies for Space – a ground up overview, Online, Portugal
125. **T. C. Scott**; 2021; *Galaxy Clusters: What we are learning from cold gas in late type galaxies*; The Past, Present and Future of the VLA: Celebrating 40 Years, Online
126. **A. M. Silva**, **J. P. Faria**, **N. C. Santos**, **S. G. Sousa**, **P. T. P. Viana**; 2021; *A semi-Bayesian implementation of template matching for precise radial Velocities*; Statistical Challenges in Modern Astronomy VII, Online, Estados Unidos da América
127. **A. M. Silva**, **J. P. Faria**, **N. C. Santos**, **S. G. Sousa**, **P. T. P. Viana**; 2021; *A Bayesian template matching approach applied to HARPS: towards the improvement of the RV precision*; EAS 2021, Online, Países Baixos
128. **H. Silva**; 2021; *U(1) Local Strings in hybrid metric-Palatini gravity*; 16th Marcel Grossmann Meeting, Online
129. **H. Silva**; 2021; *U(1) Local Strings in generalized hybrid metric-palatini gravity*; 16th Marcel Grossmann Meeting, Online
130. **H. Silva**; 2021; *U(1) local cosmic strings in hybrid metric-Palatini gravity*; 30th Workshop on General Relativity and Gravitation in Japan, Online, Japão
131. **J. Silva**, **P. Machado**, J. Peralta, **F. Brasil**, S. Lebonnois, M. Lefèvre; 2021; *Final Results on Atmospheric Wave Characterisation on the Nightside Lower Clouds of Venus*; EPSC2021, Online
132. **T. A. Silva**; 2021; *A curious planetary system: A Dense Hot Super Mercury and a Cold Jupiter*; STARS and PLANETS in the ULTRAVIOLET: A Cross-Community Symposium, Online, Estados Unidos da América
133. **B. Soares**, **V. Zh. Adibekyan**, **N. C. Santos**, **E. Delgado Mena**, **S. G. Sousa**; 2021; *From stellar to planetary compositions*; ESO Workshop The Star-Planet Connection, Online

134. **B. Soares**, **V. Zh. Adibekyan**, **N. C. Santos**, **E. Delgado Mena**, **S. G. Sousa**, A. A. Godizov; 2021; *Chemical composition of rocky planets orbiting M dwarfs*; EANA 2021, Online

135. **L. Sousa**; 2021; *Probing cosmic superstrings with gravitational waves*; Gravitational wave probes of physics beyond the standard model, Online, Polónia

136. **S. G. Sousa**; 2021; *SWEET-CAT v2: What can homogeneous stellar parameters provide to planetary systems studies?*; PLATO WP122 Scientific Workshop #1, Online

137. G. Vieira, **P. Pina**, E. Whelan; 2021; *Landscape characterization and assessment of the recent impacts of climate change at Pingo Canadian Landmark*; ASM2021 - ArcticNet Annual Scientific Meeting, Online, Canadá

138. G. Vieira, **P. Pina**; 2021; *Remote sensing methods applied to coastal changes detection and permafrost degradation in Darnley Bay*; ASM2021 - ArcticNet Annual Scientific Meeting, Online, Canadá

139. G. Vieira, **P. Pina**; 2021; *Evaluating hydrodynamic and bathtub water-level models to assess storm surge flooding in Tuktoyaktuk*; ASM2021 - ArcticNet Annual Scientific Meeting, Online, Canadá

National Scientific Communications [75]

1. **V. Zh. Adibekyan**; 2021; *The chemical link between stars and their rocky planets*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
2. **V. Zh. Adibekyan**; 2021; *Stellar clustering and orbital architecture of planetary systems*; 2nd Planetary Systems day, Online, Portugal
3. **V. Zh. Adibekyan**; 2021; *Towards a comprehensive study of Stars and stellar systems*; Estágios de Verão IAstro 2021, Online, Portugal
4. **I. S. Albuquerque**, **N. Frusciante**; 2021; *The Scaling Cubic Galileon: Phenomenology and Cosmological Constraints*; Encontro com a Ciência e Tecnologia em Portugal, Lisboa, Portugal
5. **I. S. Albuquerque**, **N. Frusciante**; 2021; *The Scaling Cubic Galileon: Phenomenology and Cosmological Constraints*; Ciências Research Day, Lisboa, Portugal
6. **I. S. Albuquerque**, **N. Frusciante**; 2021; *The Scaling Cubic Galileon: Phenomenology and Cosmological Constraints*; Dia da Investigação do Departamento de Física, Lisboa, Portugal
7. **S. Amarantidis**, **J. Afonso**, **I. Matute**, **R. Carvajal**, **D. D. Barbosa**, A. A. Godizov; 2021; *Towards the detection of the earliest SMBHs*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
8. **D. D. Barbosa**, **J. Afonso**, **I. Matute**, **R. Carvajal**, **S. Amarantidis**; 2021; *Searching for Very Distant Radio Sources in the MIGHTEE survey*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
9. **F. Brasil**, **P. Machado**, **G. Gilli**, J. Peralta, **J. Silva**, **D. Quirino**, **D. C. Espadinha**, A. A. Godizov; 2021; *Atmospheric Gravity Waves: with Venus GCM simulations and Venus Express VMC data*; Encontro com a Ciência e Tecnologia em Portugal, Online, Portugal
10. **F. Brasil**; 2021; *Characterising Atmospheric Gravity Waves on Mars using Mars Express OMEGA images*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
11. **R. Carvajal**, **J. Afonso**, **I. Matute**, **S. Amarantidis**, **D. D. Barbosa**; 2021; *Using Machine Learning to look for high-redshift Radio Galaxies Conference*; Encontro com a Ciência e Tecnologia em Portugal, Lisboa, Portugal
12. **R. Carvajal**, **J. Afonso**, **I. Matute**, **S. Amarantidis**, **D. D. Barbosa**; 2021; *Detection of high-redshift Radio Galaxies using Machine Learning model Conference*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
13. **R. Carvajal**, **I. Matute**, **J. Afonso**, **S. Amarantidis**, **D. D. Barbosa**, **P. A. C. Cunha**, **A. Humphrey**; 2021; *Obtaining High-redshift Radio Galaxy candidates with Machine Learning*; IA-ON8, Coimbra, Portugal
14. **A. S. C. Carvalho**; 2021; *Galaxy Cluster counts with Euclid*; IA-ON8, Online, Portugal
15. **A. S. C. Carvalho**, A. Krone-Martins, H. -J. Gerber; 2021; *Unsupervised photometric galaxy clustering: Analysis of Euclid and DES bands with UPMASK*; Encontro com a Ciência e Tecnologia em Portugal, Online, Portugal
16. **A. Chougule**, **J. M. Gomes**, **P. Papaderos**; 2021; *Active Galaxies: where matter meets cosmic monsters*; Encontro com a Ciência e Tecnologia em Portugal, Online, Portugal
17. **A. Chougule**, **J. M. Gomes**, **P. Papaderos**; 2021; *An extensive collection of Seyfert 2 galaxy templates*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
18. **M. J. Conceição**; 2021; *Cosmological Density Field Emulation and Gravitational Wave Inference based on Dimensionality Reduction and Supervised Machine Learning*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
19. **J. R. C. C. C. Correia**, **C. J. A. P. Martins**; 2021; *On improving string modelling*; IberiCOS 2021, Online, Portugal
20. **M. Cortês**; 2021; *The Arrow of Time and Free Will*; Lisbon Mind & Reasoning RIP Seminar, iFilNova, Portugal
21. **I. A. Costa**; 2021; *Parcerias com os Clubes Ciência Viva na Escola*; Encontro Mobilizador - Clubes Ciência Viva nas Escolas, Porto, Portugal
22. **I. A. Costa**; 2021; *Parcerias com os Clubes Ciência Viva na Escola*; Encontro Mobilizador - Clubes Ciência Viva nas Escolas, Vila Nova de Gaia, Portugal

23. **I. A. Costa**, B. D. Fields; 2021; *Communicating Science... what for? - the Porto Planetarium - Ciência Viva Center case*; Estágios de Verão IAstro 2021, Online, Portugal
24. **I. A. Costa**; 2021; *Ciência cidadã em contexto escolar: de uma técnica investigativa a um método de ensino e comunicação de ciência – um exemplo nacional*; Encontro Nacional de Ciência Cidadã 2021, Porto, Portugal
25. **I. A. Costa**; 2021; *Astronomy fade out in portuguese compulsory schooling: a crossroads for astronomy national stakeholders*; 31st Encontro Nacional de Astronomia e Astrofísica, Online, Portugal
26. **I. A. Costa**; 2021; *A Ciência Cidadã como método de comunicação de ciência: o caso do projeto CoAstro*; 9.ª edição do Congresso Anual de Comunicação de Ciência SciComPt, Online, Portugal
27. **E. A. S. Cristo**; 2021; *Unveiling the atmosphere of HD 209458b with ESPRESSO*; 1st Planet Systems Day, Online, Portugal
28. **J. A. B. Dias**, **P. Machado**, J. L. F. Ribeiro; 2021; *Detection and limits of detection of minor chemical species in Solar System's atmospheres*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
29. **D. C. Espadinha**, **P. Machado**, **J. Peralta**, **G. Gilli**, **J. Silva**, **R. Gonçalves**, **M. Silva**, **F. Brasil**; 2021; *Cloud tracking technique and Akatsuki's space-based observations in ultraviolet*; Ciências Research Day, Lisboa, Portugal
30. **D. C. Espadinha**; 2021; *Venus dynamics: BepiColombo flyby to Venus, Akatsuki UVI and TNH-HARPS observations*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
31. **J. Gomes da Silva**; 2021; *Trends in stellar chromospheric activity*; 1st Planet Systems Day, Online, Portugal
32. **T. B. Gonçalves**, J. L. Rosa, **F. S. N. Lobo**; 2021; *Cosmology in scalar-tensor f(R,T) gravity*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
33. **P. Lagos**; 2021; *IFS studies in star-forming dwarf galaxies and group-dominant galaxies*; 1st Galaxies Day @ IA, Online, Portugal
34. **C. Leote**; 2021; *SKIES - SKilled, Innovative and Entrepreneurial Scientists*; IA-ON8, Coimbra, Portugal
35. **C. Leote**, **S. Pereira**, **J. Retrê**, **P. Machado**, **G. Gilli**, **J. Silva**, **R. Gonçalves**; 2021; *Criar um jogo de tabuleiro educativo em tempos de pandemia*; SciComPt 2021, Online, Portugal
36. **R. Lima**; 2021; *A poluição luminosa no nosso quotidiano e nos ecossistemas*; Jornadas Tecnológicas de Engenharia do Ambiente, Lisboa, Portugal
37. **R. Lima**; 2021; *Poluição luminosa: a hora de a derrotar é agora*; Webinar Poluição luminosa na Macaronésia - Ciclo Aves Marinhas, Online, Portugal
38. **R. Lima**; 2021; *Light pollution: The urgency of restoring the night in Portugal and the role of Astronomers*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
39. **R. Lima**; 2021; *Poluição luminosa: a hora de a derrotar é agora (Light pollution: the time to defeat it is now)*; Webinar Poluição Luminosa na Macaronésia - Ciclo Aves Marinhas, Online, Portugal
40. **F. S. N. Lobo**; 2021; *Modified Gravity and Cosmology*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
41. **P. Machado**; 2021; *Planets that lost their habitability*; Ciências Research Day, Lisboa, Portugal
42. **P. Machado**; 2021; *Final results of Doppler Velocimetry winds on Mars' atmosphere*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
43. **I. Matute**, **S. Amarantidis**, **J. Afonso**, **R. Carvajal**; 2021; *A clearer view of the Hot and Energetic Universe*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
44. **J. P. Mimoso**, F. Guerreiro; 2021; *Large Scale Structure Tessellation Statistics as a probe of Cosmology*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
45. **J. P. Mimoso**; 2021; *The cosmological constant in voids*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
46. **J. P. Mimoso**; 2021; *New numerical approaches to test the cosmological principle with the Euclid Mission*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
47. **J. P. Mimoso**; 2021; *Large Scale Structure Tessellation Statistics as a probe of Cosmology*; 31st Encontro Nacional de Astronomia e Astrofísica, Online, Portugal
48. **J. P. Mimoso**; 2021; *The cosmological constant in voids*; 31st Encontro Nacional de Astronomia e Astrofísica, Online, Portugal
49. **J. P. Mimoso**; 2021; *New numerical approaches to test the cosmological principle with the Euclid Mission,*; 31st Encontro Nacional de Astronomia e Astrofísica, Online, Portugal
50. **H. Miranda**, **C. Pappalardo**; 2021; *Self-consistent population spectral synthesis with Fado: III. Nebular contributions and main-sequence galaxies*; Encontro com a Ciência e Tecnologia em Portugal, Online, Portugal
51. **N. A. M. Moedas**; 2021; *Effect of turbulent mixing on stellar surface abundances*; IA-ON8, Coimbra, Portugal
52. **E. M. P. S. Moreira**, **S. Pereira**; 2021; *Science Communication overview*; IA-ON8, Online, Portugal
53. **C. Pappalardo**; 2021; *The star formation history of galaxies in spectral synthesis methods*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
54. **C. Pappalardo**; 2021; *The star formation history of galaxies in spectral synthesis methods*; Massively Parallel Large Area Spectroscopy from Space, Online, Portugal

55. **C. P. Pereira**, **M. Abreu**, **A. Cabral**; 2021; *Light source stabilization system for High Accuracy Photometry Instruments in Astronomy*; Dia da Investigação do Departamento de Física, Lisboa, Portugal
56. **C. P. Pereira**, **M. Abreu**, **A. Cabral**; 2021; *Light source stabilization system for High Accuracy Photometry Instruments in Astronomy*; Ciências Research Day, Lisboa, Portugal
57. **C. P. Pereira**, **M. Abreu**, **A. Cabral**; 2021; *Light source stabilization system for High Accuracy Photometry Instruments in Astronomy*; Encontro com a Ciência e Tecnologia em Portugal, Lisboa, Portugal
58. **C. P. Pereira**; 2021; *Stabilization of calibration light sources for High Accuracy Photometry Instruments*; IA-ON8, Online, Portugal
59. **S. Pereira**, **C. Leote**, **F. A. L. Pires**, **J. Retrê**, **T. F. S. Cunha**; 2021; *Conteúdos educativos em astronomia: estratégias e parcerias em ligação com a sociedade*; SciComPt 2021, Online, Portugal
60. **J. L. F. Ribeiro**; 2021; *A reanalysis of ISO-SWS Jupiter observations: first results*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
61. **N. M. Rosario**; 2021; *Measure the spin-up of hot-Jupiters due to tides*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
62. **I. Yu. Rybak**; 2021; *CMB from standard and current-carrying cosmic strings*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
63. **A. R. G. Santos**; 2021; *Solar and stellar magnetic activity*; Stars Day 2021, Online, Portugal
64. **A. R. G. Santos**; 2021; *Signatures of stellar magnetic activity from space-based photometry*; IA-ON8, Coimbra, Portugal
65. **A. M. Silva**, **J. P. Faria**, **N. C. Santos**, **S. G. Sousa**, **P. T. P. Viana**; 2021; *A new paradigm for the estimation of precise stellar radial velocities: towards the development of an innovative data analysis software*; IA-ON8, Online, Portugal
66. **A. M. Silva**, **J. P. Faria**, **N. C. Santos**, **S. G. Sousa**, **P. T. P. Viana**, C. Hanhart; 2021; *A semi-Bayesian implementation of template matching for precise radial Velocities*; Encontro com a Ciência e Tecnologia em Portugal, Online, Portugal
67. **J. Silva**, **P. Machado**, J. Peralta, **F. Brasil**; 2021; *Characterising Atmospheric Gravity Waves on the nightside of Venus - A Systematic Study*; Encontro com a Ciência e Tecnologia em Portugal, Lisboa, Portugal
68. J. Silva, **P. Machado**, J. Peralta, F. Brasil; 2021; *Characterising Atmospheric Gravity Waves on the nightside of Venus - A Systematic Study*; Ciências Research Day, Lisboa, Portugal
69. **J. Silva**, **P. Machado**, J. Peralta, G. Gilli, R. Hueso, **F. Brasil**, **D. C. Espadinha**, **R. Gonçalves**; 2021; *Characterising Atmospheric Gravity Waves on Venu's lower and upper cloud banks using Venus Express VIRTIS and VMC data*; Ciências Research Day, Lisboa, Portugal
70. **J. Silva**; 2021; *Final results on Nightside small scale waves on Venus*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
71. **J. Silva**, **P. Machado**, J. Peralta, **F. Brasil**, S. Lebonnois, M. Lefèvre; 2021; *Final Results on Atmospheric Wave Characterisation on the Nightside Lower Clouds of Venus*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
72. **J. Silva**, **P. Machado**, **F. Brasil**, **R. Gonçalves**; 2021; *Jupiter atmosphere exploration with ESPRESSO (VLT) and Cassini data*; IA-ON8, Online, Portugal
73. **T. A. Silva**; 2021; *Transmission spectroscopy measurements of exoplanets with ESPRESSO*; IA-ON8, Online, Portugal
74. **T. A. Silva**; 2021; *A curious planetary system: A Dense Hot Super Mercury and a Cold Jupiter*; 31st National Astronomy and Astrophysics Meeting, Online, Portugal
75. **B. Soares**, **V. Zh. Adibekyan**, **N. C. Santos**, **E. Delgado Mena**, **S. G. Sousa**; 2021; *A compositional link between rocky exoplanets and their host stars*; 2nd Planets Day, Porto, Portugal

Seminars at IA [22]

1. André, Ph.; 2021; *The role of molecular filaments in the origin of stellar masses*
2. Bellini, E.; 2021; *Sheer shear: weak lensing with one mode*
3. Bonoli, S.; 2021; *miniJPAS: a preview of the Universe in 56 colors*
4. Cantat-Gaudin, T.; 2021; *Painting a portrait of the Milky Way disc with Gaia and star clusters*
5. Castander, F. J.; 2021; *The PAU Survey*
6. Chiappini, C.; 2021; *Galactic Archaeology with precise ages, chemistry and kinematics: what have we learned?*
7. Daddi, E.; 2021; *Observing the formation of the first generations of galaxy clusters at high redshift*
8. Di Valentino, E.; 2021; *Investigating cosmic discordances*
9. Foreman-Mackey, D.; 2021; *Open-source software for probabilistic data analysis in astronomy*
10. Gil de Paz, A.; 2021; *MEGARA & TARSIS, from the highest-resolution to the widest-field 2D spectroscopy*
11. Goswami, S.; 2021; *On the effects of Initial Mass function on the galactic chemical enrichment: the role of Pair Instability Supernovae*
12. Harko, T.; 2021; *Astrophysical and cosmological implications of conformal quadratic Weyl gravity*
13. Lee, Y. J.; 2021; *Brightness modulations of our nearest terrestrial planet Venus*
14. Mainieri, V.; 2021; *AGN outflows at cosmic noon and their impact of the host galaxies*

15. Miglio, A.; 2021; *Asteroseismic ages for galactic archaeology: strengths and limitations*
16. Peter, P.; 2021; *Unitarily inequivalent quantum bouncing models*
17. Quintin, J.; 2021; *Isotropisation in the approach to a singularity*
18. Rompineve, F.; 2021; *Gravitational Waves as probe of QCD axion quality*
19. Scolnic, D.; 2021; *New Advances with Type Ia Supernovae To Measure The Expansion of the Universe*
20. Seidel, J. V.; 2021; *Hotter than Hell: Understanding highly-irradiated worlds through transmission spectroscopy*
21. Sherwin, B.; 2021; *New ways of testing cosmic tensions with galaxy surveys and CMB lensing*
22. Steindl, T.; 2021; *Putting Hayashi and Henyey behind: Combining asteroseismology and state of the art pre-main sequence models*

Organization of Conferences [11]

1. *F2F Meeting ESPRESSO*; 25 to 29 January 2021; Online, Portugal
2. *1st Planetary Systems day @ IA*; 2 February 2021; Online, Portugal
3. *1st Galaxies day @ IA*; 22 April 2021; Online, Portugal
4. *Massively Parallel Large Area Spectroscopy from Space*; 21 to 23 June 2021; Online Workshop
5. *Fundamental cosmology from the ELT and space; 4th Azores School on Observational Cosmology 6th Azores International Advanced School in Space Sciences*; 6 to 12 September 2021; Angra do Heroísmo, Açores, Portugal
6. *8th Iberian Meeting on Asteroseismology; Laying the groundwork for the road ahead*; 18 to 21 October 2021; Porto, Portugal
7. *2DEMOC*; 21 to 22 October 2021; Porto, Portugal
8. *IA-ON8*; Instituto de Astrofísica e Ciências do Espaço 8th internal workshop; 10 to 12 November 2021; Portugal
9. *2nd Planetary Systems day @ IA*; 3 December 2021; Online, Portugal
10. *Stars Day 2021*; 7 December 2021; Online, Portugal
11. *Cosmonata 2021*; 21 December 2021; Online, Portugal

Observing runs [28]

1. M. Beltran, V. Rivilla, M. S. N. Kumar; The large-scale kinematics of the protocluster G31, IRAM, 30m Telescope, 8-10 July 2021
2. S. Inutsuka, D. Arzoumanian, M. S. N. Kumar, R. Furuya; Polarization observations of S106 and W3/4 complexes to map the magnetic fields, JCMT. 9-11 August 2021
3. B. Wehbe and the NIRPS team, NIRPS FE commissioning, La Silla ESO 3.6m telescope, 2-7 December 2021
4. P. Machado, Phosphine on Venus. IRTF Telescope at MaunaKea Observatory, Hawaii, USA. Instrument TEXES, July 2021
5. C. Sengupta, T. C. Scott, Y. Chandola, H. Chen, P. Lagos, Y. Ma, D. Tramonte, H. Ye; HI observations of ultra-diffuse galaxies (UDGs) in galaxy groups; MKT-20121; MeerKAT; 15 May - 2 September 2021
6. M. Sun, F. Combes, L. Cortese, T. C. Scott, S. Sivanandam, E. Brinks, M. Fumagalli, M. Yagi, J. Palous, W. Cramer, M. Fossati, A. Boselli, A. Kabátová, R. Grossová; ALMA JELLY - Survey of Nearby Jellyfish and Ram Pressure Stripped Galaxies; 2021.1.01616.L; ALMA
7. S. Sousa, N. Santos, E. Delgado Mena, V. Adibekyan, Rojas Ayala, Mortier, P. Figueira, O. Demangeon, Israelian, S. Barros, J. Faria, M. Tsantaki, A. Antoniadis Karnavas, Know the star to know the planet: improving the catalog of exoplanet host stars with homogeneous parameters UVES, UT2@VLT ESO, SM P107
8. J. Brinchmann and the MUSE GTO team; 105.208V.001; MUSE/VLT; 2021-09-01 to 2021-09-11, P107
9. J. Brinchmann and the MUSE GTO team; 108.22AM.001; MUSE/VLT; 2021-10-03 to 2021-10-10, P108
10. J. Brinchmann and the MUSE GTO team; 108.22AM.001; MUSE/VLT; 2021-10-31 and 2021-11-02, P108
11. J. Brinchmann and the MUSE GTO team; 108.22AM.001; MUSE/VLT; 2021-11-30 to 2021-12-09, P108
12. A. R. F. Sanchez, M. L. P. Gunawardhana, M. Maseda, A. Myszka, K. Glazebrook, J. Matthee, L. Boogard, J. Brinchmann, S. Sweet; N/A; KOALA/AAT; 2021-12-28 to 2022-01-03
13. T. L. Campante, N. C. Santos, V. Adibekyan, M.S. Cunha, Pushing the boundaries of cool-dwarf asteroseismology with ESPRESSO; Program ID: 109.236P; Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO) at the Very Large Telescope (VLT); Period 109
14. C. Danielski, T. L. Campante, M. Tsantaki, E. Delgado Mena, et al.; Building a public catalogue of homogeneously characterised Ariel exoplanet-host stars; Program ID: 109.23J9; Ultraviolet and Visual Echelle Spectrograph (UVES) at the Very Large Telescope (VLT); Period 109
15. S. Grunblatt, T. L. Campante, F. Pereira, D. Veras, Planetary Archaeology: Characterizing Planet Candidates Transiting Evolved Stars; Program ID: N085; High Resolution Echelle Spectrometer (HIRES) at the W. M. Keck Observatory; Semester 2021B

16. S. Grunblatt, T. L. Campante, F. Pereira, D. Veras, Planetary Archaeology: Characterizing Planet Candidates Transiting Evolved Stars; Program ID: N098; High Resolution Echelle Spectrometer (HIRES) at the W. M. Keck Observatory; Semester 2021A
17. P. Pina, field campaign in Antarctica for developing aerial surveys with drones and collecting ground-truth data in three main sites of the South Shetlands (~62ºS), Deception Island and Livingstone Island (Hurd and Byers Peninsulas), by two members of the VEGENTANTAR2022 project, January and February 2022
18. L. Bellot, R. Gafeira; Polarization signal on Solar Spicules; NO REFERENCE; CRISP and CHROMIS on the SST telescope; 29 of June to 8 of July
19. U. Jørgensen, et al. since 2008; MiNDSTEp (Microlensing Network for the Detection of Small Terrestrial Exoplanets) 9-11 October 2021, DFOSC / Lucky Imaging - 1.5m Danish Telescope, ESO-La Silla
20. H. Messias, J. Afonso, S. Amarantidis, S. Anton, R. Demarco, E. Fomalont, E. Hatziminaoglou, P. Hibon, R. Kneissl, M. Lacy, S. Martin, B. Mason, I. Matute, T. Mroczkowski, G. Orellana Gonzalez, R. Shirley, C. Yang; Characterising the nature of the SZ-effect imprint around four radio-galaxies.; 2021.2.00047.S; ALMA 12-m array; Cycle 8
21. D. Sobral, E. Dodd, J. Calhau, T. Cornish, N. Amos, A. Jenkins, M. Cox, J. Matthee, A. Paulino-Afonso; TIHMPSS: The INT Halo Metal Poor Star Survey; C50/N3/P6; WFC/INT; September 1-7 & October 9-12 & November 4-12, 2021
22. Manara, J. F. Gameiro et al., PENELLOPE: the ESO data legacy program to complete the Hubble UV Legacy Library of Young Stars (ULLYSES) [106.20Z8.001 1106.C-1047(A) 23.8 h ESPRESSO/VLT; 106.20Z8.003 1106.C-1047(C)) 23.7 h ESPRESSO/VLT; 106.20Z8.005 1106.C-1047(E) 43.1 h ESPRESSO/VLT; 106.20Z8.009 1106.C-1047(I) 34.6 h UVES/VLT; 106.20Z8.010 1106.C-1047(J) 7.8 h UVES/VLT; 106.20Z8.011 1106.C-1047(K) 30.7 h UVES/VLT; 106.20Z8.002 1106.C-1047(B) 12.6 h XSHOOTER/VLT; 106.20Z8.004 1106.C-1047(D) 10 h XSHOOTER/VLT; 106.20Z8.006 1106.C-1047(F) 15.9 h XSHOOTER/VLT]
23. F. Pepe, O. Demangeon et al., Detection and characterization of Earth-like planets with ESPRESSO, 106.21M2, ESPRESSO at VTL, May 13 2021, P107
24. D. Armstrong, T. A. Silva et al., HARPS observer pool; HARPS 3.6m; 28 Dec - 3 Jan
25. E. Delgado Mena et al.; “RV variations in evolved stars in open clusters: planets, oscillations or stellar activity?”; 105.20AZ (moved to period 107) and 108.22LE (other observers); HARPS/ESO-La Silla 3.6m; period 108 remote observing
26. D. Armstrong, E. Delgado Mena et al.; “Uncovering the origin of remnant planets in the hot Neptunian Desert; 108.21YY, HARPS/ESO-La Silla 3.6m., P108 remote observing
27. J. Gomes da Silva et al.; “Follow-up observations of G 9-40b with ESPRESSO: A temperate super-Earth or sub-Neptune? “; 108.22BT; ESPRESSO/VLT P108 service mode
28. M. Rainer, E. Delgado Mena et al.; “A precise characterisation of the ARIEL stars“, 2021B-25, LBT/PEPSI, period 2021B

Outreach talks [161]

1. C J. Rodrigues, Détecter la Terre, serait-ce possible? Une histoire d’exoplanètes, Saint-Luc (Suíça), 29 July
2. P. Pina, Planetary pattern recognition and comparison to terrestrial analogues, Open Talk to the Earth Sciences Department from the University of Coimbra, 20 October
3. P. Pina, The impact of climate change in Polar regions, Escola Básica Conde de Arnoso, Vila Nova de Famalicão, 12 October 2021, in the frame of Polar Education Program
4. T. Scott, Galaxy Clusters: what are we learning from cold gas in late type galaxies, West of London Astronomical Society online, 12 July
5. C. Lobo, Galáxias, talk at Colégio Nossa Senhora de Lourdes (in the framework of ESERO), Porto, 28 October
6. C. Lobo, A nossa galáxia e as outras: uma viagem através do Universo, online talk in the framework of the Science and Technology Week activities organized by UP, 26 november
7. C. J. A. P. Martins, A Física da Vida e dos Extraterrestres, ES D. Sancho I, Famalicão, 12 March
8. C. J. A. P. Martins, A Física da Vida e dos Extraterrestres, ES José Falcão, Miranda do Corvo, 11 October
9. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES Al Berto, Sines, 11 October
10. C. J. A. P. Martins, A Física da Vida e dos Extraterrestres, Colégio Júlio Dinis, Porto, 12 October
11. C. J. A. P. Martins, A Física da Relatividade, ES Afonso Lopes Vieira, Leiria, 18 October
12. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Gama Barros, Sintra, 18 October
13. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Carlos Amarante, Braga, 19 October
14. C. J. A. P. Martins, A Física da Vida e dos Extraterrestres, ES Vitorino Nemésio, Praia da Vitória, Açores, 19 October
15. C. J. A. P. Martins, A Física do Big Bang, ES D Sancho I, Famalicão, 20 October
16. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Camilo Castelo Branco, Famalicão, 20 October

17. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Latino Coelho, Lamego, 22 October
18. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES de Fornos de Algodres, 22 October
19. C. J. A. P. Martins, A Física da Relatividade, ES de Sever do Vouga, 25 October
20. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES de Arga e Lima, Lanheses, 25 October
21. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES António Granjo, Chaves, 27 October
22. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Seomara Primo, Amadora, 27 October
23. C. J. A. P. Martins, A Física da Radioactividade e do Cancro, ES do Vale do Tamel, Barcelos, 28 October
24. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES da Santa Maria Maior, Viana do Castelo, 28 October
25. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES da Amadora, 29 October
26. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES Luís Dantas, Câmara de Lobos, Madeira, 29 October
27. C. J. A. P. Martins, A Física da Radioactividade e do Cancro, ES de S. Pedro do Sul, 2 November
28. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES Clara de Resende, 3 November
29. C. J. A. P. Martins, A Física da Vida e dos Extraterrestres, ES Rafael Bordalo Pinheiro, Caldas da Rainha, 4 November
30. C. J. A. P. Martins, A Física da Atmosfera e do Aquecimento Global, ES da Maia, 4 November
31. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES João Gonçalves Zarco, Matosinhos, 5 November
32. C. J. A. P. Martins, A Física da Radioactividade e do Cancro, ES de Paredes, 5 November
33. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Eça de Queirós, Lisboa, 8 November
34. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Maria Amália Vaz de Carvalho, Lisboa, 10 November
35. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Fonseca Benevides, Lisboa, 11 November
36. C. J. A. P. Martins, A Física da Radioactividade e do Cancro, ES António Bento Franco, Ericeira, 11 November
37. C. J. A. P. Martins, A Física da Radioactividade e do Cancro, ES da Bemposta, Portimão, 12 November
38. C. J. A. P. Martins, A Física da Gravidade e dos Satélites, ES Pinhal do Rei, Marinha Grande, 10 December
39. C. P. Pereira, Há Estrelas no Bairro, Parque da Bela Vista, Lisboa, Portugal, Outreach activities to observe the night sky through a telescope, 18 September
40. C. P. Pereira, Missão Espacial ARIEL: actividades Pro-Am e o Projecto ExoClock, Encontro de Astrónomos Amadores, online, Portugal, 10 April
41. C. P. Pereira, Mergulhos no Oceano Cósmico, Escola Básica do Juncal, online, Portugal, 17 March
42. C. P. Pereira, Instrumentação para o Espaço com Cédric Pereira, 52º PubhD de Lisboa, online, Portugal, 10 March
43. P. Machado, Forum Ciência Viva, Pavilhão do Conhecimento, 23 January
44. P. Machado, Ciência com Impacto (podcast), 30 January
45. P. Machado, Pergunta ao astrónomo, IAstro, 11 February
46. P. Machado, Ciências - Universidade de Lisboa, Corrida a Marte, 23 February
47. P. Machado, Busca de Vida Fora da Terra, Jornadas de Engenharia Mecânica da Universidade do Minho, 3 March
48. P. Machado, Descodificar Marte, TECMAIA, 21 March
49. P. Machado, Habitar noutros Planetas, O Universo online, 24 April
50. P. Machado, O Corpo por Vir, Culturgest, 17 May
51. P. Machado, Exploração Espacial: Até onde podemos ir?, AEIST - Associação dos Estudantes do Instituto Superior Técnico, 19 May
52. P. Machado, "O Estudo em Casa" e para os pequeninos sobre o espaço e a exploração espacial, ESA - ESERO, Ciência Viva, Pavilhão do Conhecimento, 28 May
53. P. Machado, RTP, Radar XS, do ZIG ZAG, 4 June
54. P. Machado, RTP, Radar XS, do ZIG ZAG, 21 June
55. P. Machado, BarranCosmos, Barrancos, 6 September
56. P. Machado, Noite Europeia dos Investigadores 2021, Centro Ciência Viva Constância, 24 September
57. P. Machado, The sky above us, Figueira de Castelo Rodrigo, 28 September
58. P. Machado, Atmosferas Planetárias, Escola Pedro Arrupe, 6 April
59. P. Machado, Planetary Exploration, India Online talk, 22 June
60. P. Machado, Outros Mundos, FIC.A - Festival Internacional de Ciência, Palácio e Jardins do Marquês de Pombal, Oeiras, Palestra , 12-17 October
61. J. H. C. Martins, Jornadas da Ciência, Escola Secundárias de Via Todos, 10 May

62. M. T. Barata, ISWI School 2021 Online - i4S, International Space Weather Initiative Steering Commitee Annual Meeting, virtual, 16 February
63. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Colégio de Amorim, Póvoa de Varzim (online), 18 November
64. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica n.º 2 de São Pedro do Sul (online), 17 November
65. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica e Secundária Fernão do Pó, Bombarral (online), 15 November
66. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica e Secundária Rainha D. Leonor de Lencastre, São Marcos, Sintra (online), 11 November
67. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Colégio João Paulo II, Braga (online), 10 November
68. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica e Secundária Rodrigues de Freitas, Porto, 9 November
69. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica Ave, Vila das Aves, Santo Tirso (online), 4 November
70. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica Prof. Pedro d'Orey da Cunha, Damaia, Amadora (online), 4 November
71. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica Prof. Pedro d'Orey da Cunha, Damaia, Amadora (online), 29 October
72. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica e Secundária Rodrigues de Freitas, Porto, 20 October
73. S. A. G. Sousa, À Descoberta de Planetas Extra-Solares, Escola Básica e Secundária Rodrigues de Freitas, Porto, 15 October
74. J. L. Yun, Impacto global no planeta Terra: a espécie humana e a catástrofe climática, Marinha Grande, 10 November
75. J. L. Yun, Ética e Urgência Climática: a perspectiva de um astrofísico, Fórum Ética da Universidade do Minho, 10 December
76. A. R. Liddle, The Dark Side of the Universe, India (Mumbai and other regions, via zoom), 7 July
77. J. C. Fonseca, Midi-ASPPA, online, 11 Dezembro
78. N. C. Santos, À procura de outros mundos, Semana da Ciência e Tecnologia da Universidade do Porto (online), 22 November
79. N. C. Santos, Outras Terras no Universo, Conversas Gradiva, Festival Internacional de Ciência - FICa, Oeiras, Portugal, 16 October
80. N. C. Santos, TED-X talk: Planetas Infinitos, TEDx Vila Nova de Gaia, World of Wine, Vila Nova de Gaia, 24 July
81. N. C. Santos, À procura de outras Terras, Secção de Astronomia da Associação Académica de Coimbra (online), 11 June
82. A. Cabral, Instrumentação em Astronomia: A Ciência de braço dado com a Engenharia, Agrupamento de Escolas de Moimenta da Beira (online), 15 June
83. A. Cabral, Astronomia XXL, BarranCosmos, Barrancos, 11 September
84. A. Cabral, A Magia da Luz, Noite Europeia dos Investigadores, Observatório do Lago do Alqueva, Reguengos de Monsaraz, 24 September
85. A. Cabral, A Magia da Luz e da Cor, Escola Secundária Seomara da Costa Primo, Amadora, 27 May
86. T. Barreiro, Universo Fantasma, IA (online), 27 February
87. T. Barreiro, Física fora da caixa, Univ. dos Açores (online), 31 October
88. T. Barreiro, Universo Fantasma, Escola secundária Sebastião da Gama, Setúbal (online), 24 November
89. I. Tereno, Mapping the sky between Italy and Portugal, Italy embassy in Lisbon, 26 April
90. P. M. Carvalho, Cosmologia: Um Universo Fascinante, Açores, 21 May
91. P. M. Carvalho, Da Idade da Magia a Galileu, Escola Básica e Secundária Campo Aberto, Beiriz, Póvoa de Varzim, 26 November
92. D. F. M. Folha, Biomédicas e Astronomia, Arte do desenrasque, Universidade do Minho (online), 12 March
93. D. F. M. Folha, Água no Universo, IA-Porto, in the context of IA's participation in the ESERO PT programme “O Espaço Vai à Escola“, 17 November
94. R. C. Lima, Poluição luminosa: é urgente restaurar a noite; GreenFest Carcavelos 2021; Carcavelos, Portugal (online), 14 September
95. V. Adibekyan, ISM2021 Public Talk Other Suns and other Earths in the Wilky Way, Beirut (online), 4 May
96. C. Pappalardo, Outreach Event organized by the Observatory of Alqueva, MOONS: a state-of-the-art spectrograph to unravel the evolution of galaxies, BarranCosmos, 11 September
97. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto, 20 October
98. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto 1, 21 October
99. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto 2, 21 October
100. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto 1, 22 October
101. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto 2, 22 October
102. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Gondomar, 26 October
103. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto de Mós, 28 October

104. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Gondomar, 29 October
105. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Carvalhos, 29 October
106. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Guimarães, 2 November
107. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Vila Franca de Xira, 3 November
108. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto, 3 November
109. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Porto, 4 November
110. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Guimarães, 5 November
111. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Figueira da Foz, 5 November
112. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Vila Franca de Xira, 8 November
113. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Grijó, 10 November
114. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Figueira da Foz, 17 November
115. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Guimarães, 18 November
116. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Paredes, 18 November
117. I. A. P. M. Costa, O Espaço vai à Escola, sessão para alunos do ensino básico, Ponte de Lima, 18 November
118. I. A. P. M. Costa, Espaço vai à Escola, sessão para alunos do ensino básico, Porto, 3 December
119. A. S. P. Afonso, À descoberta do nosso Universo, Virtual, October/November - 13 talks, 416 students at ages between 2-5
120. A. S. P. Afonso, À exploração do Sistema Solar, Virtual (2 in person @ Porto), October/November - 33 talks, 1099 students at the ages between 6-10
121. A. S. P. Afonso, Os mitos, a magia e os mistérios do Universo, Virtual (2 in person @ 1 in Porto, 1 in Taipas, Guimarães), October/November - 15 talks, 614 students in the 7th/8th grade
122. A. S. P. Afonso, A utilidade da Astronomia na nossa vida diária, Virtual, October/November - 9 talks, 336 students in High School
123. A. S. P. Afonso, Uma viagem pelo Universo, Virtual, October/November - 22 talks, 1055 students in the 5th/6th/7th/8th/9th grades
124. S. C. C. Barros, Entrevista para SIC, Jornal da meia noite, Equipa com astrónomos portugueses descobrem planetas que podem ter água à superficie- 6/8/2
125. M. Cortês, Why is time always moving forward and never backward? – Women in Science – NaNu – Núcleo de Nanotecnologia da FCT UNL, March
126. M. Cortês, Why is time always moving forwards and never backwards? – National Space Society (USA) - Mumbai, INDIA (Awareness towards STEM), June
127. T. de Azevedo Silva, Unveiling the composition of exoplanet atmospheres with ESPRESSO, InReach UPorto/FCUP (Online) 11 March
128. T. de Azevedo Silva, Em busca de planetas distantes, e como desvendar suas atmosferas!, Espaço vai à escola (Online), 14 October
129. T. de Azevedo Silva, Em busca de planetas distantes, e como desvendar suas atmosferas!, Espaço vai à escola (Online), 15 October
130. T. de Azevedo Silva, Espetroscopia em Astronomia; Online; 25 November
131. N. J. Nunes, Finding black holes, Escola Secundária Jaime Moniz, no Funchal, Madeira, 25 November
132. N. J. Nunes, The Autumn's sky, Escola Básica e Secundária Dr. Ângelo Augusto da Silva, Madeira, 26 November
133. N. J. Nunes, The Autumn's sky, Escola Básica e Secundária D. João V, Damaia, Amadora, 4 November
134. N. J. Nunes, The Autumn's sky, Escola Básica de Monte Abraão, Sintra, 3 November
135. N. J. Nunes, The Autumn's sky, Escola Básica Escultor Francisco dos Santos, Fitares, Sintra, 29 October
136. N. Peixinho, Do Planeta-X a Plutão e ao Planeta Nove, Ciclo Ciência às Seis no RÓMULO Centro Ciência Viva da Universidade de Coimbra, Online, 13 April
137. N. Peixinho, Astronomia, Escola de Verão de Astronomia do Núcleo de Física do Instituto Superior Técnico, Online, 11 September
138. M. S. Cunha, Ser Astrofísica, Escola EB 2/3 Dr. Pedrosa Veríssimo, 25 November
139. J. Afonso, A Ciência do Telescópio Espacial James Webb, 8a Conferência dos Professores EspAciais (online), 11 November
140. J. Afonso, O Lado Brilhante do Universo, Escola Secundária São Pedro do Sul (online), 2 November
141. J. Afonso, O Lado Brilhante do Universo, Escola Secundária José Gomes Ferreira, 26 October
142. J. Afonso, A Astronomia da Próxima Geração, Escola Básica de Abação (online), 22 October
143. J. Afonso, A Astronomia da Próxima Geração, Escola Básica de Abação (online), 29 October
144. J. Afonso, Em Busca das Primeiras Galáxias, Colégio Manuel Bernardes (online), 17 June
145. J. Afonso, O Universo Deslumbrante, Dia Nacional da Cultura Científica - Encontro 4 Elementos, FCUL, 24 November

146. J. Afonso, O Lado Brilhante do Universo, Festival Internacional de Ciência - Oeiras, 14 October
147. J. Afonso, O Lado Brilhante do Universo, Festival Internacional de Ciência - Oeiras, 16 October
148. F. S. N. Lobo, Buracos Negros: Os lugares mais secretos do Universo, Escola Básica Pedro de Santarém, 12 October
149. F. S. N. Lobo, Buracos Negros: Os lugares mais secretos do Universo, Escola Básica e Secundária Josefa de Óbidos, 19 October
150. F. S. N. Lobo, Buracos Negros: Os lugares mais secretos do Universo, Escola Luis Madureira, 21 October
151. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Escola Secundária José Gomes Ferreira, 26 October
152. F. S. N. Lobo, O Universo: Sua Formação e Constituição, Escola Básica e Secundária D. João V, Damaia, Amadora, 26 October
153. F. S. N. Lobo, O Universo: Sua Formação e Constituição, Escola Básica de Corroios, Seixal, 26 October
154. F. S. N. Lobo, Buracos Negros: Os lugares mais secretos do Universo, Escola Básica Pedro de Santarém, 28 October
155. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Escola Básica e Secundária D. Martinho Vaz de Castelo Branco, 28 October
156. F. S. N. Lobo, O Universo: Sua Formação e Constituição, Escola Básica e Secundária D. João V, Damaia, Amadora, 28 October
157. F. S. N. Lobo, O Universo: Sua Formação e Constituição, Escola Básica e Secundária D. João V, 28 October
158. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Externato de S. José, 2 November
159. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Escola Secundária do Arco-Íris, 4 November
160. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Escola Secundária do Arco-Íris, 9 November
161. F. S. N. Lobo, Ondas Gravitacionais: A sinfonia cósmica que abalou o mundo, Colégio de São João de Brito, 9 November

Reports [6]

1. E. Duarte, PLATO mission, PLATO-UOL-PDC-DD-0007, On-ground COB to Sky positions ATBD, issue1.1, 1.2, 1.3, May-July, 2021 (report)
2. E. Duarte, PLATO-UOL-PDC-DD-0006, Centers of Brightness Calculation ATBD, issue 1.0, 1.1, February-March, 2021 (report)
3. E. Duarte, PLATO-UOL-PDC-DD-0005, Star CCD position Calculation ATBD, issue 1.1, February, 2021 (report)
4. E. Duarte, PLATO-UOL-PDC-DD-0004, On-ground Attitude Estimation ATBD, issue 1.0, 1.1, 1.2, 1.3, May-November, 2021 (report)
5. E. Duarte, PLATO-UOL-PDC-TN-0001, Attitude Estimation methods, Justification Document, issue 3, 30.04.2021 (report)
6. E Duarte, PLATO-UOL-PDC-TN -0002, Centroid Determination, Justification Document, issue 6, 20.12.2021 (report)

External seminars by IA researchers [26]

1. **V. Adibekyan**; The Chemical link between stars and their rocky planets; Exocoffee, online 30 Mar 2021
2. **V. Adibekyan**; The Chemical link between stars and their rocky planets; MPIA, Heidelberg, Germany, online 7 Jun 2021
3. **V. Adibekyan**; Rocky planets, made of star-stuff; Yerevan Physics Institute, Yerevan, Armenia, online 2021
4. **G. Fanizza**; Precision cosmology in the era of Large-Scale-Structure surveys; University of L'Aquila, Italy; 7 May
5. **G. Fanizza**; Hubble diagram and precision cosmology; University of Geneva, Switzerland; 29 October
6. **G. Fanizza**; Cosmic Variance and Hubble diagram at higher redshifts; CERN, Switzerland; 10 November
7. **C. J. A. P. Martins**; Astrophysics Training and Research Opportunities at CAUP, PLANCKS 2021 Meeting, Online, 8 May
8. **C. J. A. P. Martins**; Varying Fundamental Constants, from Alpha to Omega, OCA Lagrange Seminar, Online, 11 May
9. **M. S. Nanda Kumar**; Filaments to Clusters: An inclusive paradigm of formation for all stellar masses; University of Leeds, UK, 28th October
10. **M. S. Nanda Kumar**; Filaments to Clusters: An inclusive paradigm of formation for all stellar masses; University of Cardiff, Wales, UK. 4th November
11. **M. S. Nanda Kumar**; Filaments to Clusters: An inclusive paradigm of formation for all stellar masses; University of Hertfordshire, Hatfield, UK. 5th November
12. **I. Rybak**; Cosmic (super/superconducting) strings as a probe of high energy physics; ICRANet Pescara, Italy; 22 September
13. **M. Deal**; Transport of chemical elements in stars: Lithium abundance dispersion in metal-poor stars, LESIA, Meudon, France, November
14. **M. Deal**; Transport of chemical elements in stars: Lithium abundance dispersion in metal-poor stars, LUPM, Montpellier, France, November

15. **M. Deal**; Transport of chemical elements in low-mass main-sequence stars, Université de Genève, Online, March 2021
16. **P. Machado**; Physics Seminar - DF-FCUL (invited), Planetary Atmospheres: From Solar System to Exoplanets, 10 November
17. **N. C. Santos**; The quest for other Earths through the eyes of ESPRESSO", European Astrobiology Institute, online, 30 November
18. **N. C. Santos**; Studying the stars, knowing the planets, institute of computational sciences at the UZH, Zurich, Switzerland, zoom, 18 June
19. **N. C. Santos**; Planetary Systems at IA: an overview, First IA-CITEUC Meeting, 29 January
20. **N. C. Santos**; Chromatic Rossiter: The case of HD209458b and beyond, NIRPS WG3 meeting, 22 January
21. **P. A. C. Cunha**; Debating the potential of machine learning in astronomical surveys, IAP, Paris, France; 18-22 October
22. **N. Frusciante**; Probing modified gravity with cosmology and solutions to the Hubble tension; CRAG, Sheffield (UK) - virtual; 9 June
23. **N. Frusciante**; Modified gravity models after GW170817: Phenomenology and cosmological bounds; ICG Portsmouth (UK) - virtual; 10 Feb
24. **E. Delgado Mena**; The chemistry of stars; University of Valladolid (Spain), 8th June
25. **E. Delgado Mena**; Carbon and C/O ratios for Galactic stellar populations and planet hosts; University of Bologna (Italy) (online), 6th Dec
26. **N. Peixinho**; To Neptune and beyond!; Department of Physics of the Faculty of Sciences and Technology of the University of Coimbra, Portugal, 29 September

PhD Completed [10]

1. B. Akinsanmi, 2021, Looking for rings and tides in transiting exoplanets, Doctoral Program in Astronomy (3rd cycle), Supervisor(s): **S. C. C. Barros**, **S. Santos**
2. B. Wehbe, 2021, Atmospheric Dispersion Correction for High Resolution Astronomical Instruments, Doctoral Program in Astronomy (3rd cycle), Supervisor(s): **A. Cabral**, G. Avila
3. B. J. Barros, 2021, An exotic universe: from dark energy to wormholes, Doutoramento em Astronomia e Astrofísica (ULisboa), Supervisor(s): **N. J. Nunes**, **T. Barreiro**
4. F. T. O. Cabral, 2021, Towards a new spacetime paradigm. Gauge theories of gravity and post-Riemann geometries. Applications to Cosmology, particle physics and Gw probes, Doutoramento em Astronomia e Astrofísica (ULisboa), Supervisor(s): **F. S. N. Lobo**, D. Rubiera-Garcia
5. L. F. Pereira, 2021, Detection and characterization of planets orbiting oscillating red-giant stars with NASA's TESS mission, Doctoral Program in Astronomy (3rd cycle), Supervisor(s): **T. L. Campante**, **M. S. Cunha**, **N. C. Santos**
6. R. Gonçalves, 2021, Planetary atmospheres – From Solar System to Exoplanets, Doutoramento em Astronomia e Astrofísica (ULisboa), Supervisor(s): **P. Machado**
7. S. Hojjatpanah, 2021, The awakening of the ESPRESSO planet-hunter: finding a twin of Earth, Doctoral Program in Astronomy (3rd cycle), Supervisor(s): **P. Figueira**, **N. C. Santos**
8. S. N. Reis, 2021, Photometric and spectroscopic tracers of the inside-out growth of massive galaxies, Doutoramento em Astronomia e Astrofísica (ULisboa), Supervisor(s): **I. Matute**
9. S. Amarantidis, 2021, Towards the detection of the earliest supermassive black holes with the future radio and X-ray surveys, Doutoramento em Astronomia e Astrofísica (ULisboa), Supervisor(s): **J. Afonso**, **I. Matute**
10. V. M. C. Ferreira, 2021, Unveiling the dark side of the universe: unified dark energy and the role of small-scale clustering, Doctoral Program in Astronomy (3rd cycle), Supervisor(s): P. **P. Avelino**, **I. Tereno**

MSc Projects Completed [10]

1. A. P. Rodrigues, 2021, Biases in weak lensing measurements of galaxy simulated images, Master in Physics (FCUL), Supervisor(s): **I. Tereno**
2. A. R. R. Almeida, 2021, Analytic Models for Realistic Cosmic Strings, Master in Astronomy, Supervisor(s): **C. J. A. P. Martins**
3. B. Soares, 2021, Composition of terrestrial planets orbiting M dwarfs, Master in Astronomy (UPorto), Supervisor(s): **V. Zh. Adibekyan**
4. B. A. R. Rocha, 2021, New Maps of the Dark Side: redshift drift cosmography, Master in Astronomy (UPorto), Supervisor(s): **C. J. A. P. Martins**
5. H. Cerviño Asorey, 2021, The star-disk interaction in Youg Stellar Objects, Master in Astronomy (UPorto), Supervisor(s): **J. F. Gameiro**
6. H. Miranda, 2021, The FADO of SDSS galaxies, Master in Physics (FCUL), Supervisor(s): **C. Pappalardo**
7. H. M. R. da Silva, 2021, Cosmic Strings in Modified Theories of Gravity, Master in Astronomy (UPorto), Supervisor(s): **F. S. N. Lobo**, **P. P. Avelino**
8. M. P. Júlio, 2021, Exploration of dark matter profiles in ultra-faint dwarfs: the curious case of Antlia B, Master in Astronomy (UPorto), Supervisor(s): **J. Brinchmann**
9. P. A. C. Cunha, 2021, Investigating Obscured Quasars at High Redshift using Machine Learning, Master in Astronomy (UPorto), Supervisor(s): **A. Humphrey**

10. V. da Fonseca, 2021, Testing dark energy couplings, Master in Physics (FCUL), Supervisor(s): **N. J. Nunes**

BSc Traineeships / Projects completed [108]

(under the supervision of IA researchers)

1. Cristina Meng, Measurement of emission-lines in extragalactic objects, Programa de Estágios Extra-Curriculares da FCUP (PEEC), february-july 2021.
2. Axel Lapel (Nice), New Maps of the Dark Side: The redshift drift, February-September, M2 Internships
3. Julien Poyatos (Clermont-Ferrand), Testing the universality of physical laws: from ESPRESSO to the ELT, February-September, M2 Internships
4. Thomas Raveau (Montpellier), From string theory to observational cosmology, February-September, M2 Internships
5. Catarina Marques (UNL): Optimization of spectroscopic tests of fundamental physics: from ESPRESSO to the ELT, February-September, MIEF Internship
6. Júlio Oliveira, Astrophysical tests of fundamental physics: scale invariant models, PEEC 2020-21
7. Diogo Pinheiro, Astrophysical tests of fundamental physics: scale invariant models, PEEC 2020-21
8. Francisco Ferreira, Tests of the universality of physical laws: phenomenological parametrizations, PEEC 2020-21
9. Pedro Marto, Tests of the universality of physical laws: phenomenological parametrizations, PEEC 2020-21
10. Filipe Costa, Simulating and visualizing strings with GPUs and CUDA, PEEC 2020-21
11. Francisco Pimenta, Astrophysical tests of fundamental physics: runaway dilatons, PEEC 2020-21
12. Mafalda Matos, Development of astrophysics contents for secondary education, PEEC 2020-21
13. Aurora Rubio, Ionospheric disturbances: sources on the Sun and their consequences near the ground level, a student project in the frame of the Iberian Space Science Summer School 2021 - i4s, July 26-30, 2021, on-line
14. Carolina Carmo, Ionospheric disturbances: sources on the Sun and their consequences near the ground level, a student project in the frame of the Iberian Space Science Summer School 2021 - i4s, July 26-30, 2021, on-line
15. Elena Marshalko, Ionospheric disturbances: sources on the Sun and their consequences near the ground level, a student project in the frame of the Iberian Space Science Summer School 2021 - i4s, July 26-30, 2021, on-line
16. Marco Cintra, Ionospheric disturbances: sources on the Sun and their consequences near the ground level, a student project in the frame of the Iberian Space Science Summer School 2021 - i4s, July 26-30, 2021, on-line
17. Suniti Singh, Ionospheric disturbances: sources on the Sun and their consequences near the ground level, a student project in the frame of the Iberian Space Science Summer School 2021 - i4s, July 26-30, 2021, on-line
18. Martim Dams, Giant Hub-Filament Systems, summer student, 12th-30th July 2021
19. Yuri Damasceno, Giant Hub-Filament Systems, summer student, 12th-30th July 2021
20. Jarno Sandrin, Identifying and Characterizing AGN in Next-Generation Radio Surveys Using Machine and Deep Learning, Summer Internship Project, 12-30 July 2021
21. Pedro Ferreira, Identifying and Characterizing AGN in Next-Generation Radio Surveys Using Machine and Deep Learning, Summer Internship Project, 12-30 July 2021
22. Pedro Rodrigues, Identifying and Characterizing AGN in Next-Generation Radio Surveys Using Machine and Deep Learning, Summer Internship Project, 12-30 July 2021
23. Adriana Monteiro, Identifying and Characterizing AGN in Next-Generation Radio Surveys Using Machine and Deep Learning, Summer Internship Project, 12-30 July 2021
24. Ahmed Labib, The 200: Exploring the most active supermassive black holes in the first Gyr of the Universe, Summer Internship Project, 12-30 July 2021
25. Maria Eduarda Pimentel, The 200: Exploring the most active supermassive black holes in the first Gyr of the Universe, Summer Internship Project, 12-30 July 2021
26. Luis Barroso, The 200: Exploring the most active supermassive black holes in the first Gyr of the Universe, Summer Internship Project, 12-30 July 2021
27. João Rato, The 200: Exploring the most active supermassive black holes in the first Gyr of the Universe, Summer Internship Project, 12-30 July 2021
28. Beatriz Resendes, Identifying and characterizing AGN in next-generation radio surveys with machine learning, Project for the course Astrophysics Laboratory at FCUL-UL, October 2021 - January 2022
29. José Lopes, Modelling Active Galactic Nuclei with Machine Learning, Project for the course Astrophysics Laboratory at FCUL-UL, October 2021 - January 2022
30. Pedro Vicente Marto, Cosmic strings as a window to the early universe, Estágios de Verão IAstro, 12-30 July 2021
31. Maria Catarina Cruz Figueira, Cosmic strings as a window to the early universe, Estágios de Verão IAstro, 12-30 July 2021
32. Maria I. Ferreira, Asteroseismology: an exploratory tour of the oscillations in red giant stars, IAstro Summer Internships Program, July 2021

33. Carlos Perez, Asteroseismology: an exploratory tour of the oscillations in red giant stars, IAstro Summer Internships Program, July 2021
34. Rafael Silva, Atmospheric gravity waves on Mars, (ongoing) 2021
35. Bruna Fena, How known planets from the Solar System would be seen if they were exoplanets, (ongoing) 2021
36. Diogo Quirino, Modelização da atmosfera de Vénus utilizando o Planetary Spectrum Generator (PSG), 2020-2021
37. Nicolau Fialho, Search for molecules with astrobiological relevance on Mars, (ongoing) 2021
38. Alexandre Branco, Transmission Spectrosocpy on Venus and exoplanet's atmospheres, (ongoing) 2021
39. Antonio Miguel Braçais Correia, Measuring IR radial velocities with SPIRou: testing the LBL method, Projeto em Astrofísica (FCUP: AST3011), March 2021 to June 2021
40. Yuri Damasceno, Measuring the size of exoplanets with CHEOPS, Undergraduate last year project
41. Raul Liquito, An important step for understanding exoplanets: Spectroscopy of solar-type stars, PEEC-Extra-curricular project FCUP; 1 February 2020 – 31 Jly 2021
42. Inês Machado, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
43. Kelly Matsui, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
44. Iara Tiago, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
45. Inês Heitor, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
46. Mafalda Silva, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
47. Ana Carina Costa, Fora da caixa: como motivar para a ciência?, IA Summer Internship in Science Communication, 12-30 July 2021
48. Ana Cunha, creation of educational short film animation in Astronomy Literacy, internship of bachelor students in Animation Arts of Lusófona University, August - October 2021
49. Sara Dábrio, creation of educational short film animation in Astronomy Literacy, internship of bachelor students in Animation Arts of Lusófona University, August - October 2021
50. Sílvia Tang, creation of educational short film animation in Astronomy Literacy, internship of bachelor students in Animation Arts of Lusófona University, September - November 2021
51. José Marques, Todos os caminhos levam ao Espaço, internship in Science Communication, November 2021 - January 2022
52. Bruno Alexandre Alves Lourenço, Laboratório de Astrofísica, Sept-Dec 2021
53. Diogo Cunha; Fora da caixa: como motivar para a ciência?; Science Communication project; IAstro Summer Internships; 12th-30th July 2021
54. Tatiana Mendes, The star formation and chemical enrichment histories of galaxies: A casestudy with BAGPIPES and FADO, Projecto em Astrofísica (FCUP), 7 October 2021 - 14 January 2022
55. Barbara Silva Oliveira, Exoplanet composition and stellar abundances, October 2021 - January 2022, Projecto em Astrofísica (FCUP)
56. Yuri Carrilho Damasceno, Measuring the size of exoplanets with CHEOPS, October 2021 - January 2022, Projecto em Astrofísica (FCUP)
57. Ana Paulino, Stellar activity indicators: exploring H-alpha, programa de estágios do IA, 12-30 Jul 2021
58. Telmo Monteiro, Stellar activity indicators: exploring H-alpha, programa de estágios do IA, 12-30 Jul 2021
59. Afonso Mota, Exoplanet composition and stellar abundances, aluno da FCUL, trabalho no âmbito da cadeira Laboratório de Astrofísica, October 2020 - January 2021
60. Ayoub Ait Benhamou, Galactic Archaeology with NASA's TESS space mission, Predoctoral Internship Erasmus+ (2021)
61. Bruno Vale Fernandes, Classifying galaxy morphology on cluster galaxies using machine learning, Masters Project, 2021, 2022
62. Paul Charpentier, Developing codes for exoplanet detection with N-body simulations, Internship, 7 July - 27 August
63. Sandie Marion, Uncovering Stellar Activity with Machine Learning, Internship, 7 July - 27 August
64. João Azevedo, Optimized transformations of the lensing convergence field with genetic algorithms, start: May 2021
65. Silvia Costa, Estágio empresarial no laboratório de óptica, June - December 2021
66. Mariana Pinto, Characterazing radio AGNs in the SKA precursor survey RACS, internship, March - July 2021
67. Margarida Rodrigues, Estimating redshifts with Machine & Deep Learning, internship, October 2021 - June 2022
68. João Santos, AGN demographics through ATHENA simulations, short-project for Astrophysics Laboratory (FCUL, 3rd year of Physics degree), October 2021 - January 2022
69. Carlos Perez, Asteroseismology: an exploratory tour of the oscillations in red giant stars, IA summer internship, 12-30 August

70. Maria I. Ferreira, Asteroseismology: an exploratory tour of the oscillations in red giant stars, IA summer internship, 12-30 August
71. Ana F. F. Ferreira, Influência da utilização de aparelhos electrónicos no sono em crianças do 1.º ciclo, graduation project (Clinical Physiology 4y-degree), School of Health of the Polytechnic of Porto, September 2020-July 2021
72. David Pereira, Cosmological probes of dark energy, October 2021 - February 2022
73. Simao Marques Nunes, Cosmological probes of dark energy, October 2021 - February 2022
74. Maria Guadalupe Mendonça, Modified gravity: the no slip gravity model, October 2020 - February 2021
75. Francisco Lima, Exploring the impact of dark energy on cosmological observables, October 2020 - February 2021
76. Hilberto Silva, Exploring the impact of modifications of gravity law on cosmological observables, July 2021
77. Rafael Soares, Exploring the impact of modifications of gravity law on cosmological observables, July 2021
78. Anselmo Falorca, Exploring the impact of modifications of gravity law on cosmological observables, July 2021
79. Francisco Balde, Exploring the impact of modifications of gravity law on cosmological observables, July 2021
80. Tomas Sousa, The CMB: a phenomenological study, July 2021
81. Dafne Bandeira, The CMB: a phenomenological study, July 2021
82. Joao Goncalves, Searching for SMBH in the early Universe. FIR peakers, Laboratorio de Astrofisica October 2020 - February 2021
83. Cristina Alexandra da Silva Carvalho, Ciências da Educação, Licenciatura, janeiro a maio
84. Mariana Barbosa, Educação Básica, Licenciatura, janeiro a abril
85. Maria Inês Rebelo, Educação Básica, Licenciatura, janeiro a abril
86. Bárbara Silva Oliveira, Binary twin stars with significantly different compositions, IAstro Summer Internships Program, 12-30 July
87. Natália Parrode, Rotation of stars with planets: combining ESPRESSO with TESS, IAstro Summer Internships Program, 12-30 July
88. Bárbara Silva Oliveira - Exoplanet composition and stellar abundances, Projecto em Astrofísica (FCUP), 1 Oct - 31 Dec 2021
89. Killian Srowlik, Simulating the Theory of the Adjacent Possible, Laboratory Project, October - December 2021
90. Francisco Lucas, Photometry of ice-bearing bodies of the outer solar system, Project course unit of the BSc on Physics of the University of Aveiro, 10 January - 28 July 2021.
91. Gabriel Róis, Black hole shadows and photon rings, Laboratório de Astrofísica, September 2021 - February 2022
92. Pedro Carvalho, Traversable wormholes in modified gravity and their use for interstellar travel, Laboratório de Astrofísica, September 2021 - February 2022
93. Sara Durão, Scaling solution with 3-form dark energy
94. Alexandre Monforte, $\alpha = 1/137$?
95. Jaime Simões, Constraining a Horndeski dark energy model with standard sirens
96. Bernardo Campilho, The impact of stellar C/O ratios on planet formation, research grant (BIM), October - December 2021
97. Juliana Amaral, Testing the core physics of evolved stars using space-based data, Project in Astronomy, Curricular Unit of BSc in Physics, University of Porto
98. Ahmed Labib, Exploring the most active supermassive black holes in the first Gyr of the Universe, BSc project, October 2021 - February 2022
99. Marta André Botas, Cosmologia com galáxias: padrões de tesselação e vazios cósmicos, from the 12-28 of July 2021, Internships at IA
100. Artur Guerreiro, Cosmologia com galáxias: padrões de tesselação e vazios cósmicos, from the 12-28 of July 2021, Internships at IA
101. Pedro Fanha, Cosmologia com galáxias: padrões de tesselação e vazios cósmicos, from the 12-28 of July 2021, Internships at IA
102. Bruno Lourenço, Cosmologia com galáxias: padrões de tesselação e vazios cósmicos, from the 12-28 of July 2021, Internships at IA
103. Artur Guerreiro, Time domain Astronomy: Following the tesselation of the Universe, Astrophysical Laboratories, October 2020-February 2021
104. Marta André Botas, The study of Voids in the Universe, Astrophysical Laboratories, October 2020-February 2021
105. Lucas Monteiro, Scaling solutions in Bianchi I models with anisotropic stress, Astrophysical Laboratories, October 2020-February 2021
106. Duarte Branco, Can galaxy clusters reveal the local correlation and fractal dimension of the Universe?, Astrophysical Laboratories, October 2021-February 2022
107. Daniela Lopes, The redshift drift in LTB models, Astrophysical Laboratories, October 2021-February 2022
108. Henrique Esgalhado, Matter over Time, Astrophysical Laboratories, October 2021-February 2022

COVER PICTURE Illustration of Planet formation around a Sun-like star, with the building blocks of planets - rocks and iron molecules - in the foreground. (Credit: Tania Cunha (Planetário do Porto - CCV & IA)

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