Book of Abstracts

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Session 2 - Extragalactic: AGN

AGN: A Tale of Accretion and Cosmic Feedback

Israel Matute (Instituto de Astrofísica e Ciências do Espaço, Faculdade de Ciências da Universidade de Lisboa)
Overview Talk

The co-evolution of supermassive black holes (SMBHs) and their host galaxies, critically shaped by Active Galactic Nuclei (AGN) phases and feedback, is a central theme in astrophysics. This talk will provide an overview of our current understanding of SMBH birth and growth, traced by AGN, up to the highest redshifts, including the most recent discoveries and questions raised by the James Webb Space Telescope (JWST). It will then focus on the contributions and future scientific aspirations of our team at the Instituto de Astrofísica e Ciências do Espaço (IA). We will finally discuss Portuguese key involvement in the development and exploitation of upcoming major facilities poised to dramatically advance our understanding of the role that SMBHs play in the context of galaxy formation up to the highest redshifts: ESO's MOONS (VLT) and MOSAIC (ELT) for comprehensive AGN demographics; ESA's NewAthena X-ray observatory for probing accretion physics and obscured growth; and the SKA precursors (and SKA itself) for investigating jet feedback and gas reservoirs.

Status on GRAVITY(+) results on active galaxies

Paulo Garcia (Universidade do Porto/CENTRA)
Co-authors: Gravity+ Collaboration
Focus Talk

GRAVITY is a powerful instrument that enables phase-referenced optical/infrared interferometry for the very large telescope interferometer. In this talk, we will review recent results obtained by the instrument on active galaxies. GRAVITY achieved the first spatial resolution of an AGN BLR, detecting rotation in the nearby quasar 3C 273. This allowed a dynamical measurement of the central supermassive black hole mass $(2.6 \pm 1.1) \times 10^8 M_\odot$, confirming fundamental reverberation mapping assumptions. These results were extended to higher redshifts with a luminous quasar at z=2.33 (J0920), whose BLR rotation was detected, yielding a dynamical BH mass of $3.2 \times 10^8 M_\odot$. GRAVITY measurements of the AGN hot dust continuum have shown a tight dust radius-luminosity relation. Interferometric dust sizes are approximately twice those derived from reverberation mapping, likely due to dust structure geometry. Dust continuum sizes can be used to estimate BLR radii and BH masses with accuracy comparable to traditional methods. Finally, I'll highlight how GRAVITY+ will enable similar studies for a much larger sample of AGNs.

The effect of extended radio emission on SMBH accretion rate estimates

Stergios Amarantidis (Institut de Radioastronomie Millimetrique (IRAM))
Contributed Talk

Current Active Galactic Nuclei (AGN) unification models correlate the broadness of optical emission lines in radio galaxies to the accretion disk physics of their Super-Massive Black Holes. Their accretion rates are commonly estimated using optical and total radio flux measurements, including emission from the core, jets, and lobes of the galaxy. However, while optical and core radio emission trace the ongoing accretion episode, extended jet and lobe structures may result from past AGN activity. Therefore, accretion rates inferred from spatially unresolved radio observations may be systematically overestimated, a bias whose prevalence and extent have yet to be thoroughly explored. In this study, using a sample of 121 local radio-loud galaxies with spatially resolved radio components, we assess this effect by estimating their Eddington-scaled accretion rates (λ) using both the state-of-the-art methodology which considers total radio fluxes and a novel approach that treats core and extended emission as signatures of distinct accretion phases. Our results show that the former method systematically overestimates the (λ) by factor of $\sim$3, leading to an accretion mode misclassification for $\sim$11% of sources. This discrepancy appears to correlate with radio size, with the most extended galaxies indicating a transition in accretion disk mode. Such a bias could significantly affect AGN classification in unresolved high-redshift radio surveys. Finally, our results reinforce the AGN unification model for radio galaxies, revealing a more direct correlation between accretion disk physics and optical spectral properties.

A Complete Characterisation of Ultra Steep Spectrum Sources in the COSMOS Field

Davi Barbosa (IA-Lisboa)
Co-authors: J. Afonso, I. Matute, R. Carvajal, B. Arsioli, H. Miranda, D. M. Santos, C. Pappalardo, E. Worrell, I. Whittam and I. Heywood
Contributed Talk

Ultra Steep Spectrum (USS) radio sources have been successfully used to select powerful radio galaxies at high redshifts ($z > 2$). Generally understand that this radio excess emission is due to an Active Galactic Nuclei (AGNs). Typically surveys of large-sky are for relatively bright radio flux densities, gradually it has become possible to extend the USS search to new sensitivity levels, thanks to a new generation of radio surveys produced by Square Kilometre Array, so-called SKA-pathfinders. Combining recent observations from the MeerKAT International Gigahertz Tiered Extragalactic Explorations (MIGHTEE) at 1.22 GHz (24 cm) and Very Large Array (VLA) at 3 GHz (10 cm) toward the two square degree Cosmic Evolution Survey (COSMOS) field, usually called VLA-COSMOS we identify $\sim$ 500 USSs, the majority of which also have optical/near-infrared measurements and redshift (spectroscopic and photometric) estimates. Using comprehensive multi-wavelength dataset available over this field, we are able to extensively characterise this population, investigate the efficiency of the USS radio criteria to reach the highest redshifts at the faintest radio fluxes, of clear relevance to the preparation of future SKA surveys. We find that the faint USS source population does

not show significant differences from the broader sub-mJy radio population, in particular revealing a large number of star-forming galaxies with a redshift distribution peaking at z < 1. This work probes the effectiveness of the USS criteria down to faint flux levels and suggests that an additional criteria can be explored for a refined selection of distant radio galaxies, in particular in the upcoming SKA-era.

A radio view of galactic size evolution: the machine learning approach

Rodrigo Carvajal (Instituto de Astrofísica e Ciências do Espaço - Universidade de Lisboa)
Co-authors: J. Afonso; I. Matute
Contributed Talk

A comprehensive study of how galaxy sizes evolve across cosmic time is needed to understand the formation history of galaxies and the Universe. In standard models, galaxy sizes are expected to decrease with increasing redshift, particularly when traced via rest-frame UV/optical emission. However, recent observations (with JWST and ALMA) have revealed a more diverse population at high redshift, suggesting a possible flattening of the size-redshift relation (e.g. Cheng et al. 2024; Sun et al. 2024) or a size evolution only at extreme redshifts (e.g. Fudamoto et al. 2022; Allen et al. 2025). At radio wavelengths, galaxy size measurements face additional challenges due to contamination from AGN-related structures such as jets and lobes. This effect is especially relevant when studying the high-redshift Universe, which has only recently become accessible to deep wide-area radio surveys (e.g. Jiménez-Andrade et al. 2019 and references therein). Addressing these challenges, particularly the obscuration by AGN activity, calls for robust methods for distinguishing compact host galaxy emission. We apply the radio-galaxy ML-based selection pipeline from Carvajal et al. (2023) to infrared-detected sources exhibiting compact radio morphologies in the 300 deg2 of the EMU Pilot Survey. This region has lacked deep radio-based size analyses, making it a compelling environment for new studies. We present the radio sizes of sources selected by our method, and investigate their redshift evolution, establishing direct comparison with optical/infrared size measurements and providing a new foundation for future size measurements at radio wavelengths.

Unveiling the Properties of Extreme Emission Line Galaxies at Cosmic Noon with JWST

Henrique Miranda (Instituto de Astrofísica e Ciências do Espaço/Faculdade de Ciências da Universidade de Lisboa)
Co-authors: Ciro Pappalardo, José Afonso
Contributed Talk

Studying extreme emission line galaxies (EELGs) is crucial, as they reflect a key phase that most galaxies undergo during their evolution and closely resemble the properties of galaxies in the young universe, providing valuable insights into galaxy formation and evolution. In this work, we present the preliminary results from a spectroscopic analysis of a growing sample of EELGs at Cosmic Noon, identified in the DAWN JWST Archive. In our analysis we employ the population spectral synthesis (pss) code FADO, which self-consistently models both the optical stellar and nebular continuum, crucial for accurately interpreting the spectra of galaxies with significant contribution of the nebular emission to the total observed emission. Importantly, as virtue of being a pss code, FADO does not require a predefined star formation or chemical enrichment history, allowing it to capture the bursty nature of these systems without imposing priors. Through a uniform analysis of this spectroscopic sample, we aim to characterize the physical and evolutionary properties of EELGs at Cosmic Noon. The preliminary results indicate that EELGS are typically young, low-mass and metal-poor systems. Moreover, their star formation histories are dominated by recent intense bursts, consistent with the observed high equivalent widths of [OIII] λ 5007 and Hα. These findings emphasise the importance of detailed modelling to better understand the nature and evolution of these galaxies.

Unveiling faint X-ray AGN populations in the NewAthena era: Insights from cosmological simulations

Nuno Covas (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Israel Matute, Stergios Amarantidis, José Afonso, Giorgio Lanzuisi, Andrea Comastri, Stefano Marchesi, Ciro Pappalardo, Rodrigo Carvajal, and Polychronis Papaderos
Poster

Recent observations expanded our understanding of galaxy formation and evolution, yet key challenges persist in the X-ray regime, crucial for studying Active Galactic Nuclei (AGN). These limitations drive the development of next-generation observatories such as ESA's NewAthena. Now in phase B (preliminary design), the mission requires extensive testing to ensure compliance with its scientific goals, particularly given the uncertainties surrounding high redshift AGN. This work leverages the IllustrisTNG cosmological simulation to build an X-ray AGN mock catalogue and assess the performance of NewAthena's WFI. We created a Super Massive Black Hole (SMBH) light cone, spanning 10 deg2, with corrections to account for the limited resolution of the simulation and X-ray properties derived in post-processing. The resulting catalogue reveals a 5× overabundance of faint AGN compared to current X-ray constraints, an inconsistency potentially resolved by invoking a higher Compton-thick (CTK) fraction and intrinsic X-ray weakness, as suggested by recent JWST findings. An end-to-end survey simulation using SIXTE predicts ∼250,000 AGN detections, including ∼20,000 at $z > 3$ and 35 in the Epoch of Reionization ($z > 6$); notably, only AGN with $L_X > 10^{43.5}$ erg s^{-1} are detectable at $z > 6$. The analysis also forecasts a significant population of detectable CTK AGN, even beyond $z > 4$. These findings suggest X-ray observations will, for the first time, probe a significant AGN population in the EoR, offering new insights into SMBH growth. They also provide key input for refining NewAthena's mission design and optimizing its survey strategy.

What lurks around the most massive supermassive black holes? A simulated view.

Filipa Morgado (Institute of Astrophysics and Space Sciences - FCUL)
Co-authors: José Afonso
Poster

One of the most challenging and exciting frontiers in current astrophysical knowledge is galaxy formation. The fundamental observation of objects well within the first Gyr of the Universe is still scarce, and theory is unavoidably uncertain about the mechanisms ruling galaxy build-up at those early ages. What we currently do know is that accretion into massive black holes, fundamental for galaxy assembly, is already well established as early as 800 Myr after the Big Bang. In particular, the recent detection of powerful quasars at those epochs imply an amazingly rapid growth, previously considered impossible, of supermassive black holes. Although observations are still very limited, the exploration of state-of-the-art simulations of galaxy formation and evolution can provide a better, self-consistent understanding of how supermassive black holes form and grow, and their impact on their environments. The results, while simulation-dependent, will inform about possible ways for quasar evolution, and will be directly comparable with current observational results and may even suggest new observational strategies to confirm the evolution of the most extreme SMBHs in the Universe. In this project, we use the Simba cosmological simulation to study the neighbourhoods of the most massive SMBHs in the simulation, trying to understand their relation with their environments, and contrasting such views with those from more "normal" SMBHs. We discuss the implications for models of black hole evolution, and eventual strategies to identify such objects in the distant Universe.

Revealing AGN host galaxies and their physical properties with INLA-SPDE reconstructions

Rodrigo Cosme (Faculdade de Ciências da Universidade do Porto (FCUP))
Co-authors: Ana Paulino-Afonso
Poster

Accurately estimating the physical properties of galaxies hosting active galactic nuclei (AGN), such as stellar mass, star formation rate, and stellar age, is challenging due to the presence of unresolved nuclear emission. Classical approaches like GALFIT (Peng et al., 2002, 2010) model the observed light with analytic functions to separate AGN and host components, but may oversimplify galaxies, especially when their morphology deviates from analytical profiles. Recent alternatives, such as diffusion-based inpainting methods developed for Euclid (e.g. Euclid Collaboration, Stevens et al., 2025) and deep-learning frameworks like PSFGAN (Stark et al., 2018), aim to more flexibly recover the host light. However, these methods often rely on training data or assumed profile shapes, which can limit their applicability. In this talk, we present a work that applies a statistically grounded approach using the Integrated Nested Laplace Approximation with the SPDE model (INLA-SPDE; Rue et al., 2009; Lindgren et al., 2011) to reconstruct AGN-contaminated galaxy images. We select 13 spectroscopically confirmed AGN from the Chandra-COSMOS Legacy survey (Marchesi et

al., 2016) and use imaging from the 3D-HST survey (Skelton et al., 2014) conducted with the Hubble Space Telescope in optical and near-infrared bands. After masking the central AGN region, INLA-SPDE infers missing pixel information based on spatial correlations, without imposing predefined analytic profiles. We compare this reconstruction to GALFIT Sérsic+PSF modelling, extract photometry with SExtractor (Bertin & Arnouts, 1996), and estimate physical properties using BAGPIPES (Carnall et al., 2018). Across all filters and galaxies, we find that INLA-SPDE yields photometry and derived parameters consistent with GALFIT-based results. Notably, the median differences between methods are 0.03 dex for stellar mass estimates, 0.6 solar masses per year for star formation rate estimates, and 0.01 Gyr for age estimates. Moreover, INLA-SPDE better preserves morphological complexity, which is particularly relevant for galaxies with irregular structures. While more computationally intensive, this method seems to offer a robust alternative or complement to ML-based (machine learning) approaches, particularly in the Euclid and JWST era, where accurate AGN-host separation will be critical for galaxy evolution studies.

Binaries in the Galactic Centre

Rodrigo Silva (University of Coimbra/FEUP)
Co-authors: Alexandre C. M. Correia, Paulo J.V. Garcia
Poster

The Galactic Center (GC) hosts a population of massive stars orbiting near the central supermassive black hole (SMBH), collectively known as the S-cluster. Unlike massive stars found elsewhere in the Galaxy, which commonly reside in binary systems, the S-cluster appears to lack such companions. This discrepancy may reflect observational limitations or the effects of strong dynamical interactions near the SMBH. We explore the stability and survivability of binary systems in this extreme environment. The implications of our results for the formation history and dynamical evolution of stars in galactic nuclei, and may guide future observational searches for hidden companions in the GC.

The Astronomical Potential of the RAEGE-Az Radio Telescope: Probing AGN nature from variability studies

Pedro Martins (Instituto de Astrofísica e Ciências do Espaço (IA))
Co-authors: José Afonso, Valente Cuambe, Israel Matute, João Lin Yun, Cirino Pappalardo
Poster

The RAEGE Network (Rede Antlântica de Estações Geodinâmicas e Espaciais), is a joint Spanish-Portuguese infrastructure of geodetic stations. One of these stations, located in Santa Maria, Azores, stands out as a facility within national territory with significant potential for research and education in radio astronomy. It holds particular relevance to enhancing Portugal's capabilities towards the upcoming Square Kilometre Array era. Over the past three years, under a collaborative agreement between the Institute of Astrophysics and Space Sciences and RAEGE-Az, a project has been initiated to implement a monitoring program of Active Galactic Nuclei (AGN). To this end, regular observations have been conducted on a

sample of radio-loud (> 1 Jy) AGN, with redshifts ranging z 0.02-2.4, in order to ascertain the capabilities of the Santa Maria telescope. The observations were performed within the range of the VGOS broadband spectrum (2-14 GHz) with a bandpass of 1.5 GHz, to derive spectral indexes. Here we report the results of these observations, in preparation for the monitoring program.

MOONS

Ciro Pappalardo (IA-Lisbon)
Poster

Binary and Offset AGNs Through Gaia Astrometry and Multiwavelength Analysis

Konstantinos Zafeiropoulos (University of Coimbra)
Co-authors: Sonia Anton
Poster

Active Galactic Nuclei (AGNs), powered by accreting supermassive black holes (SMBHs), play a central role in galaxy evolution. According to hierarchical galaxy formation models, galaxies and their SMBHs grow through mergers. During this process, binary SMBHs (BSMBHs) form as galaxies approach coalescence, and in some cases, post-merger SMBHs experience recoil/kick due to asymmetric gravitational wave emission, producing offset SBMHs (KSMBHs). Despite theoretical predictions, observational confirmations of both BSMBHs and KSMBHs remain scarce, with the detected number significantly lower than simulations predict. Volonteri et al. (2022) estimated that the fraction of binary within the AGN population of the same luminosity to be around 0.6%. We aim to address this observational gap by leveraging the microarcsecond-level astrometric accuracy of Gaia Data Release 3 (DR3) in combination with high-resolution sub-arcsecond radio data. By cross-matching Gaia DR3 sources with multi-wavelength datasets, we identify radio-loud AGN candidates that are offset from their host galaxy centers, as well as binary systems with sub-kiloparsec separations. Here, we present the most promising candidates discovered so far and highlight their key properties. When complete the results of this study will provide critical constraints on SMBH merger timescales, improving our understanding of AGN dynamics and their role in galaxy evolution.

Session 3 - Extragalactic: Galaxies

Galaxies

Jarle Brinchmann (ESO)
Overview Talk

Powering the search of LAEs with transformers for large-scale extragalactic surveys

Ana Paulino-Afonso (IA-UPorto/CAUP)
Contributed Talk

As surveys like Euclid begin to deliver massive imaging catalogues, there is a growing need for methods that can generalise across different filter sets and instruments. In this talk, I will present PLATES – Powering the search of LAEs with Transformers for large-scale Extragalactic Surveys – which aims to prove the use of transformers as a tool for generalizing capabilities across multiple data domains. The pilot project builds on the success of developing models for detecting and characterising LAEs from known surveys, which achieve 90% accuracy based on the COSMSO2020 photometric catalogue. We will show the application of these models over the Euclid Q1 deep fields, which cover 25 times more area and can dramatically expand the list of known LAE candidates in the Universe without the need for narrow-band filters or spectroscopic pre-selection. The preliminary tests highlight the potential of using transformer architectures to build unified tools for extragalactic science, with the potential to extend these capabilities to detect other source types (e.g., Hα emitters, AGN, among others) and estimate physical parameters (stellar mass, star-formation rates, and others). The long-term goal is to support the community with publicly available models that can be used across surveys to accelerate the discovery and characterization of high-redshift galaxies.

NGC1277: The First Massive Galaxy Without Dark Matter

Fernando Buitrago (Universidad de Valladolid / Instituto de Astrofísica e Ciências do Espaço)
Contributed Talk

NGC1277 seems not to be special, since it is a massive (stellar mass $\sim 1.5{\times}10^{11}\ M_{\odot}$) S0 galaxy that resides in the Perseus Cluster. However, it is a relic galaxy – and actually, the most extreme one – due to its remarkable compactness (effective radius $\sim$ 1.2 kpc) and its ancient stellar populations, which appear to be untouched since their very high redshift formation epoch. Additionally, NGC1277 hosts only red globular clusters and exhibits a bottom-heavy initial mass function (IMF) across all radii. Recently, we used Jeans dynamical modeling in Comerón et al. (2023) to reveal an extraordinary deficiency of dark matter in this galaxy. We found that the dark matter fraction within five effective radii is less than 5 per cent, with a 2-sigma confidence level. This raises profound questions: How could such a galaxy form? Does this pose a challenge to the ΛCDM paradigm? We demonstrate that galaxies like NGC1277 can naturally form within ΛCDM without requiring exotic explanations. Our analysis (Contreras-Santos et al. 2024) suggests that such systems can emerge as a result of multiple pericenter passages within their parent cluster. During these interactions, tidal forces progressively strip the less bound matter. Over time, this process should also affect not only the outer dark matter halo but also the central stellar component – a hypothesis supported by our findings. Using Euclid's Early Release Observations data (Buitrago et al., in prep.), we confirm that the stripping signatures are indeed evident in NGC1277's stellar component. Euclid's unparalleled depth, spatial resolution, and near-infrared capabilities herald a new era for low surface brightness studies. As the nearest (~ 73 Mpc) red nugget galaxy accessible to us, NGC1277 serves as an ideal testbed to better understand this galaxy population. Our presentation will focus on this intriguing system and whether its dark matter deficiency could explain the rest of its exceptional properties. In addition to the science contents, I will also try to put in context the Portuguese–Spanish astronomical relationship, giving a big "Parabéns" from the other side of the border in this SPA's 25th anniversary.

Exploring the genesis of spiral galaxies: Classical and pseudo bulges as extremities of a continuous sequence

Iris Breda (UniVie)
Co-authors: Polychronis Papaderos
Contributed Talk

A tantalizing enigma in extragalactic astronomy concerns the chronology and driving mechanisms of the build-up of late-type galaxies (LTGs). The standard scenario envisages two formation routes, with classical bulges (CBs) assembling first in a quick and violent quasi-monolithic episode followed by gradual disk assembly, and pseudo-bulges (PBs) progressively forming over gigayear-long timescales through gentle gas inflow from the disk and in situ star formation. The expectation from this antagonistic rationale is the segregation of present-day LTG bulges into two evolutionary distinct groups, which is in sharp contrast with recent observations. The present study aims for a thorough investigation of the star formation history (SFH) of LTGs with its ultimate goal being to outline a coherent framework for the formation and evolution of spiral galaxies and their main stellar components. Using population spectral synthesis models, we analyse the spatially resolved SFH of bulges and disks of 135 LTGs from the CALIFA survey, covering the relevant range in LTG mass. Complementarily, characteristic physical properties of bulges and disks, such as mean colours, mass- and light-weighted stellar age and metallicity, and EW(Hα), were contrasted with predictions from evolutionary synthesis models, by adopting exponentially declining SFHs with e-folding times τ between 0.1 and 20 Gyr. Analysis of the SFH of roughly half a million spaxels consistently reveals that the main physical and evolutionary properties of both bulges and disks are continuously distributed across present-day total stellar mass $M_{*,\mathrm{T}}$. The τ in spiral galaxies with

$\log(M_{*,\mathrm{T}}) > 10$ increases from the centre to the periphery, suggesting that these systems grow in an inside-out fashion. Quite importantly, the radial gradient of τ in an individual galaxy increases with increasing $M_{*,\mathrm{T}}$, which is consistent with a high bulge-to-disk age contrast in high-mass spirals, while lower-mass LTGs display roughly the same τ throughout their entire radial extent, with intermediate mass galaxies in between. Predictions obtained through evolutionary synthesis are overall consistent with observed properties. Finally, bulges and disks of higher mass galaxies exhibit shorter formation timescales as compared to their lower mass counterparts. Collectively, the obtained results evince a coherent and unified picture for the formation and evolution of LTGs, in which PBs and CBs denote extremities of a continuous mass sequence. Our findings are consistent with the framework where bulges are assembled jointly with their parent disks by gradual inside-out growth, at a pace that is regulated by the depth of the galactic potential. This postulate is further supported by the fact that the revealed correlations are entirely devoid of a bimodality, as it would be expected if CBs and PBs were to emerge from two distinct formation routes.

The density profile and dynamical centre of Sculptor

Afonso Vale (Instituto de Astrofísica e Ciências do Espaço (IA/CAUP) - FCUP)
Co-authors: Jarle Brinchmann, Catarina Lobo
Contributed Talk

The Sculptor dwarf spheroidal galaxy is one of the most extensively studied satellite galaxies of the Milky Way, offering a valuable laboratory for understanding dark matter and galaxy formation on small scales. Building on a rich legacy of observational data, the MUSE-Faint survey has targeted the central regions of Sculptor, believed to host its dynamical centre, with deep integral field spectroscopy. Through these observations, we have increased the number of stars with high-quality spectroscopic measurements by approximately 300, significantly enhancing the kinematic dataset in the central region of the galaxy. In this project, we combine the new MUSE-Faint data with an extensive compilation of archival spectroscopic and astrometric measurements from the literature, including precise stellar proper motions from Gaia and other sources. This allow us to place stringent constraints on the inner density profile of the dark matter halo in Sculptor. We then use these constraints to test and compare theoretical models of dark matter, including cold dark matter (CDM), self-interacting dark matter (SIDM), and fuzzy dark matter (FDM). Additionally, the improved spatial and kinematic coverage of the central region enables us to refine the position of the galaxy's dynamical centre – an important parameter for dynamical modeling and for interpreting the formation history of Sculptor. The results of this study contribute to our broader understanding of the nature of dark matter and the dynamical evolution of dwarf spheroidal galaxies.

On the challenge of interpreting color maps of high-z starburst galaxies with the JWST and Euclid

Polychronis Papaderos (Instituto de Astrofísica e Ciências do Espaço - Centro de Astrofísica da Universidade do Porto)
Co-authors: Göran Östlin (Stockholm University)
Poster

Morphology and color patterns provide fundamental insights into the early formation history of starburst galaxies at high z. However, a 2D reconstruction of the rest-frame properties of such systems from multi-band imaging data is a highly non-trivial task. This is mainly due to the fact that their spectral energy distribution is spatially inhomogeneous, thus the usual practice of applying a spatially constant "morphological" k-correction tailored to their integral (luminosity-weighted) SED is generally inadequate. In addition, color maps of high-z starburst galaxies are strongly affected by intense emission lines moving in and out of filter passbands depending on z, and, if taken at face value, they can lead to serious misinterpretations with respect to the nature and physical properties (e.g., age, stellar surface density and intrinsic extinction) of these systems. The significance of this problem is demonstrated using simulated color maps of the blue compact galaxy Haro 11 out to $z \sim 5$.

On the hunt for Post-Starburst galaxies

Carlota Luz (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Ciro Pappalardo, Israel Matute
Poster

Galaxies observed in the last decade have shown that the number of stars produced in the Universe has not been constant over the last 13 billion years. In the first 3–4 billion years, galaxies formed stars at a growing rate, while the last 10 billion years have seen a quite rapid decline of activity. This evolution of star formation rate in the Universe results in a dichotomy between galaxies, where we can identify objects with ongoing star formation and other types of galaxies characterised by a low or even absent star formation. Intermediate between these two categories is a subsample occupying the so-called green valley, formed by galaxies migrating from the blue cloud to the red passive region through a process called "quenching". The quenching could be a secular process, which takes several billion years, producing a smooth trend, or it could be an abrupt mechanism, followed by a passive evolution of the last generation of stars left. In this last case, galaxies could undergo a post-starburst (PSB) phase, with the co-existence of old and young stellar populations. In this work, we investigate in detail the various evolutionary phases of galaxies, specifically focusing on PSB systems. We base our work on a sample with 248,307 sources at $0.5 < z < 3.5$ from the COSMOS2020 dataset, where we use UVJ color-color diagrams to analyze and classify the galaxies into star-forming, quiescent, and green valley galaxies. With CIGALE simulations, we reproduce the COSMOS data and classify PSB as galaxies that have a quenching timescale lower than 0.7 Gyr. Our results indicate that while the absolute number of passive galaxies decreases with redshift, the percentage of PSB systems increases, reaching $\sim 31\%$ at $z \sim 2.5$ and $\sim 2\%$ at $z \sim 1.0$, which aligns with previous studies. Lastly, we also find evidence that the speed

of transition from star-forming to passive galaxies depends on redshift: a slow quenching at lower redshifts and a fast quenching at higher redshifts. After the peak of star formation and quiescence, quenching mechanisms tend to become more secular, leading to slower quenching timescales and a lower fraction of PSB galaxies. Before the peak, quenching mechanisms are dominated by faster processes, resulting in shorter timescales and a higher fraction of PSB systems.

Studying the radial profiles and mass assembly history of a sample of MAGPI galaxies at $z \sim 0.3$

Federica Mauro (University of Vienna)
Co-authors: Boso Ziegler, Iris Breda, Polychronis Papaderos, and the MAGPI team
Poster

Previous research on high-redshift spiral galaxies often emphasized their global properties while overlooking the distinct bulge and disk components, which have different star formation and chemical enrichment histories. These variations affect their spectral energy distributions (SEDs) and mass-to-light ratios, complicating accurate characterization. This study addresses these limitations by employing high-resolution integral field spectroscopy from the MAGPI survey ($z \sim 0.31$) for spatially resolved analyses of galaxy structures. Utilizing advanced spectral synthesis tools like FADO and Starlight, we derive spatially resolved stellar population properties, including mass assembly histories (MAH) for bulge-dominated and disk-dominated regions. By combining these results with Sérsic-based surface brightness decompositions, we investigate effective and half-mass radii to trace the growth of bulge and disk components. Preliminary findings show radial variations in stellar age and metallicity, reflecting the unique assembly pathways of bulge and disk regions. Ongoing work aims to create synthetic UV-through-IR SEDs to study component evolution across the range of $0 < z < 2$. These efforts intend to address the Chromatic Surface Brightness Modulation Effect (CMOD) in scaling relations, ultimately enhancing our understanding of galaxy formation and evolution since cosmic noon.

Session 4 - Planets and Extrasolar Planets

The Quest for Other Earths

Nuno Santos (IA DFA-FCUP)
Overview Talk

Following the detection of the first planet orbiting a solar-type star back in 1995, exoplanet research has become one of the key science drivers for new instruments and missions by the main international agencies (ESO, ESA, NASA). One of the main drivers of the field is the detection of other "Earths" and the detection of life-signatures in an alien world. In this talk I will briefly present the efforts done in the Instituto de Astrofísica e Ciências do Espaço to develop this field. In the process I will present some high impact results led by the team, and show our future plans.

Solar System

Alexandre Correia (University of Coimbra)
Overview Talk

This presentation offers an overview of the Solar System, focusing on the dynamics and interactions that govern the behaviour of its planets and satellites. It highlights key processes such as orbital evolution, tidal forces, and rotational dynamics that influence the stability and configuration of planetary bodies. By examining these mechanisms, it provides insights into the formation, long-term evolution, and current architecture of the Solar System. This synthesis of recent advances in celestial mechanics and planetary science aims to enhance our understanding of how complex gravitational interactions shape our cosmic neighbourhood.

Chromatic Doppler Tomography: A Novel Approach to Investigate Atmospheric Winds in Hot Jupiters

Mariana A. F. de M. e Sousa (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Carolina Lovis, Nuno C. Santos, Pedro Figueira, Olivier D. S. Demangeon, Susana C. C. Barros, Olivier Attia, Sérgio G. Sousa, João P. Faria, Pedro M. Cunha, Ana M. Silva, Raphael Martins
Contributed Talk

Atmospheric winds on hot Jupiters play a crucial role in heat and energy redistribution. One of the few tools able to constrain wind patterns is high-resolution transmission spectroscopy, which provides wind velocities from shifts in atmospheric spectral lines. However, it remains challenging to disentangle such velocities from stellar activity, planetary rotation, or tidal locking. We present a novel approach that uses **Chromatic Doppler Tomography (CDT)**, a technique that analyzes the distortions of the stellar line profile during transit across multiple wavelengths. CDT was applied for the first time to data from ESPRESSO to study the atmosphere of WASP-189b, a hot Jupiter orbiting an A-type star. We detect a clear chromatic signature of the planet atmosphere, and by isolating the spectral line distortions in different passbands, we retrieve wind velocities as a function of altitude. This chromatic Doppler tomography enables the measurement of atmospheric wind patterns in a way that is less sensitive to systematics and does not rely on prior knowledge of the planetary orbital geometry. Our analysis suggests strong equatorial eastward jets in the upper atmosphere and confirms the presence of Rayleigh scattering and metal absorption at different atmospheric layers. The method opens new possibilities for characterizing exoplanet atmospheres with ESPRESSO and upcoming instruments such as ANDES on the ELT.

TOI-512: ESPRESSO and TESS unveil a new Super-Earth around a K-type star

José Rodrigues (Instituto de Astrofísica e Ciências do Espaço / U.Porto, OFXB)
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Contributed Talk

We present the discovery and characterization of TOI-512b, combining TESS photometry with ESPRESSO radial velocity measurements to reveal a super-Earth orbiting a bright K0-type star. The relatively low stellar activity of TOI-512 made it an excellent target for ESPRESSO's high-precision capabilities. With a mass of $3.57^{+0.53}_{-0.55}$ $M_\oplus$ and radius of 1.54 ± 0.10 $R_\oplus$, TOI-512b has a bulk density of $5.62^{+1.59}_{-1.28}$ g/cm^3, indicating a predominantly rocky composition with minimal atmospheric content. Interestingly, TOI-512b receives about 127 times Earth's insolation, positioning it in a region where both gas-rich sub-Neptunes and rocky super-Earths are known to coexist. This system is particularly valuable as TOI-512b joins a select group of just 69 well-characterized planets (with mass and radius precision better than 20% and 10% respectively) in the transitional 40–250 $S_\oplus$ insolation range. While a second candidate (TOI-512.02) was initially announced, we find no evidence for it in either our ESPRESSO radial velocities or a detailed analysis of the TESS photometry. In this talk, I will use the precise characterization of TOI-512b to provide new insights for understanding the mechanisms that shape the observed radius valley between rocky planets and their gas-rich counterparts in this crucial transitional regime. Our work showcases the synergy between space-based transit surveys and state-of-the-art RV instruments in expanding our understanding of small planet compositions.

Dynamical origin of Theia, the last giant impactor on Earth

Duarte Branco (Institute of Astrophysics and Space Sciences)
Co-authors: Pedro Machado, Sean N. Raymond
Contributed Talk

Cosmochemical studies have proposed that Earth accreted roughly 5–10% of its mass from carbonaceous (CC) material, with a large fraction delivered late via its final impactor, Theia (the Moon-forming impactor). Here, we evaluate this idea using dynamical simulations of terrestrial planet formation, starting from a standard setup with a population of planetary embryos and planetesimals laid out in a ring centered between Venus and Earth's orbits, and also including a population of CC planetesimals and planetary embryos scattered inward by Jupiter. We find that this scenario can match a large number of constraints, including (i) the terrestrial planets' masses and orbits; (ii) the CC mass fraction of Earth; (iii) the much lower CC mass fraction of Mars, as long as Mars only accreted CC planetesimals (but no CC embryos); (iv) the timing of the last giant (Moon-forming) impact; and (v) a late accretion phase dominated by non-carbonaceous (NC) bodies. For this scenario to work, the total mass in scattered CC objects must have been 0.2–0.3 $M_\oplus$, with an embryo-to-planetesimal mass ratio of at least 8, and CC embryos in the 0.01–0.05 $M_\oplus$ mass range. In that case, our simulations show there are roughly 50-50 odds of Earth's last giant impactor (Theia) having been a carbonaceous object — either a pure CC embryo or an NC embryo that previously accreted a CC embryo. Our simulations thus provide dynamical validation of cosmochemical studies.

The atmospheric composition and dynamics of WASP-178b

Yuri Damasceno (Instituto de Astrofísica e Ciências do Espaço / Universidade do Porto)
Co-authors: Pedro Figueira, Olivier D. S. Demangeon, Nuno C. Santos, Pedro M. Cunha, Ana M. Silva, Carolina Lovis, Susana C. C. Barros, Romain Allart, João P. Faria, and the ESPRESSO GTO team
Contributed Talk

WASP-178b is an ultra-hot Jupiter orbiting an A-type star every 3.3 days. These extreme conditions result in significant atmospheric heating and the presence of atomic and molecular species not commonly seen in cooler exoplanets. Using high-resolution ESPRESSO spectra, we investigate the atmospheric composition and wind dynamics of WASP-178b via transmission spectroscopy. Our analysis reveals clear signatures of neutral metals, particularly Fe I, in the planet's atmosphere. We also report strong evidence for day-to-night winds from Doppler-shifted absorption features in the line profiles, reaching velocities of up to several km/s. These measurements are consistent with predictions of atmospheric circulation models for tidally locked hot Jupiters. Additionally, we explore the altitude dependence of wind patterns by performing a cross-correlation of the transmission signal across multiple pressure levels. The derived wind profile suggests the existence of a jet-like structure in the equatorial regions and potential variation with altitude. These findings contribute to our understanding of heat transport mechanisms and atmospheric escape in highly irradiated gas giants. The results underscore the power of ESPRESSO for atmospheric studies and motivate future ob-

servations with higher S/N and broader spectral coverage, especially in anticipation of the capabilities of ANDES on the ELT.

Leveraging the Sun to Enable the Detection of Earth Twins

Khaled Al Moulla (Instituto de Astrofísica e Ciências do Espaço (IA-CAUP))
Poster

The HARPS-N solar telescope and HELIOS–the solar telescope connected to the HARPS and NIRPS spectrographs–both deliver high S/N, disk-integrated Sun-as-a-star observations at a high cadence. Their provided wealth of spectra enables precise monitoring of solar activity, telluric contamination and instrumental systematics at both the spectral level and in the extracted radial velocities (RVs). In this talk, I'll give an overview of how current and next-generation solar telescopes–such as the IA-led Paranal solar ESPRESSO Telescope (PoET)–can be used to leverage the Sun to better understand the variability patterns in stars potentially hosting Earth twins. We search for optimal tracers of stellar activity, crucial for the identification of apparent RV shifts which mimic or shroud true planetary signals, and we investigate the chromaticity of the stellar activity and its temporal correlation with the RVs derived from optical and near-infrared spectra.

Modelling magnetic solar activity with SOAP4.0: improving RV precision for exoplanet detection

Alba Barka (Instituto de Astrofísica e Ciências do Espaço (IA/CAUP) - FCUP)
Co-authors: Nuno Santos, Ângela Santos, Eduardo Cristo
Poster

Advances in high-resolution spectroscopy have pushed radial velocity (RV) precision to 10 cm/s, but stellar magnetic activity remains a major limitation, mimicking or obscuring planetary signals. No definitive method has fully disentangled these effects. In this work, we successfully model the RV and photometric variations induced by stellar activity–specifically spots and faculae–using the new SOAP4.0 code. Surface features from HMI and AIA SDO images are identified using different methods, applied to simulate their impact, and compared with HARPS-N and VIRGO/SPM solar data. After subtracting the modeled activity signal to the observed solar data, the residuals reach ~m/s precision, approaching the 80 cm/s granulation limit identified by Meunier et al. (2015). This precision is constrained by incomplete physical modeling, which, with further refinement, could enable the 10 cm/s precision needed to detect Earth-like exoplanets. Furthermore, we demonstrate that different methods for identifying active regions lead to significantly discrepant results, greatly influencing the resulting RV precision. To enhance our understanding of stellar activity, the Paranal solar ESPRESSO Telescope (PoET) has been developed. This telescope, connected to ESO's ESPRESSO spectrograph, will provide high resolution disk-resolved and disk-integrated data, refining techniques for distinguishing stellar activity from planetary signals in RV measurements.

Study of Venus' atmospheric dynamics using Doppler Velocimetry techniques and VLT/UVES data

Tiago Barreiros (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Pedro Machado, Rafael Rianço Silva
Poster

On Venus, the circulation up to the cloud tops is characterised by an increasing zonal wind in the retrograde direction, the retrograde zonal superrotation, which circles the planet in 4.4 days, contrasting with the long rotation period of the solid globe (243 terrestrial days), with winds varying by tens of m/s over both long and short timescales. In the lower mesosphere (65–85 km), visible observations of Doppler shifts in solar Fraunhofer lines have provided the only Doppler wind measurements near the cloud tops in recent years. In this study we provide direct wind velocity measurements using visible Fraunhofer lines scattered by Venus cloud tops. The Doppler shift measured is the result of the motion between the Sun and Venus upper clouds particles, and the motion between the observer and Venus clouds. In this work we use ground-based Doppler velocimetry measurements of the zonal winds, based on high resolution spectra from the UV–Visual Echelle Spectrograph (UVES) instrument at ESO's Very Large Telescope, more specifically the red arm CD#3 centered at 580nm. This method allows the simultaneous direct measurement of the zonal velocity across a range of latitudes and local times in the day side. The spectrograph probes the radiation scattered by the top cloud layer, which corresponds to the maximum speed of zonal superrotation (near 70km), where $\tau \sim 1$. The small width of the UVES slit compared to the size of the disk makes it possible to characterize the spatial variations of zonal wind as a function of latitude. Since instantaneous spatial information is preserved along the slit, the spatially varying wave motions can be separated from the zonal component, which is constant along latitude circles, if the slit is aligned perpendicularly to the rotation axis. We then characterize latitudinal and longitudinal wind profiles, to study wind variability and to constrain the effect of large-scale planetary waves, in the maintenance of the superrotation. We also cross-validate the results with those from VEx and Akatsuki's cloud tracking technique missions.

Following the water on Mars

Eduardo Caetano (Faculdade de Ciências da Universidade de Lisboa)
Co-authors: Pedro Machado, Zita Martins
Poster

Mars shows undeniable evidence of the presence of liquid water in its past; however, now only remnants of its aqueous past are left. When we look at the Martian surface, we see that, between the northern and southern hemisphere, there is a huge discrepancy in the number of impact craters. One possible attempt at answering this problem was done by the scientists behind the Chinese rover Zhurong [Xiao et al., 2023], which detected what could be sedimentary ocean floor rocks. This means that there is a chance that the lack of small-medium sized impact craters is due to an ancient Borealis ocean. Another big question that this leaves behind is: what can we do to better understand this side of Martian history? Recent observations show that we do not truly understand the liquid past of our neighbouring

planet, yet. In situ studies, such as the Zhurong rover, would provide the best data sets, however, it is a very costly and very meticulous process and it should not be the only method relied upon. Doing space-based reflectance studies of the martian surface has recently gained a lot more relevance with the discovery of low altitude hydrated silica (opals) as well as low-mid altitude water ice. Both ESA's Mars Express (MEX) [Ruesch et al., 2012], and NASA's Mars Reconnaissance Orbiter (MRO) [Ehlmann et al., 2009] are crucial for these kinds of studies. In the framework of the present study, we used OMEGA (MEX) and CRISM (MRO) to study the reflectance of the surface of Mars, and look for opals, water ice and serpentines along the potential shore line of the Borealis ocean. The areas of interest are: a geological formation below the Sedona Crater, in the Isidis Planitia- Lat: 17.26943°, Lon: 77.41548° and a deltaic deposit above the Ismeniae Fossae- Lat: 45.09275°, Lon: 38.18631°. Our work in short:

- We identified and characterized morphological evidence related to fluvio-marine environments on Mars.
- We used OMEGA (MEX) and CRISM (MRO) spectra data sets to do reflectance studies and identify different minerals present in these past fluvio-marine environments.

Understanding the Effect of Solar Activity in Different Activity Levels using HELIOS/HARPS and HARPS-N Data

Pedro Branco (IA/FCUP)
Co-authors: Nuno C. Santos, João Gomes da Silva
Poster

The Radial Velocity (RV) method is a key tool for detecting and characterizing exoplanets. Stellar activity related phenomena can, however, pose a significant challenge in this quest. In this study, we used high precision solar spectra, obtained with the HELIOS/HARPS and HARPS-N solar telescopes, together with NASA SDO images, to explore the connection between the radial velocities, the magnetic field data, the facula and sunspot coverages, and different stellar chromospheric activity proxies (CaII, H-alpha), at phases of low- and intermediate-activity levels. We examined how these factors correlate, showing that in periods of moderate solar activity, the CaII activity proxy is extremely well correlated with the unsigned magnetic field. Additionally, we modeled the Sun's RV by linearly combining different activity indicators, evaluating its efficacy to correct for the signatures of stellar activity. We further show that CaII remains, together with the unsigned magnetic flux, an excellent proxy for stellar activity induced RVs.

Winds and Waves on Mars' atmosphere using ExoMars/TGO CaSSIS

Henrique Eira (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Pedro Machado, Rafael Rianço Silva
Poster

The Martian atmosphere shows a wide range of large-scale phenomena, including waves and jet streams. Recent observations suggest that a variety of waves, such as gravity waves and thermal tides, play a key role in transporting energy and momentum, especially at high altitudes. However, measuring wind velocities on Mars remains challenging. In this study, we use images from CaSSIS (Colour and Stereo Surface Imaging System) onboard the ExoMars Trace Gas Orbiter to track atmospheric features and estimate wind velocities. We apply cloud-tracking techniques using CaSSIS' high-resolution colour images, focusing on dust and ice clouds in the middle atmosphere. These techniques allow the identification of coherent features in sequential images and their displacement, enabling the calculation of horizontal wind vectors. We present measurements from different Martian seasons and latitudes, highlighting zonal wind profiles and the presence of wave patterns. Furthermore, we identify periodic structures in the vertical and horizontal direction, which may be linked to gravity waves. These measurements help to improve our understanding of the circulation and wave activity in the Martian middle atmosphere and provide constraints for general circulation models. Our results highlight the potential of high-resolution imaging in planetary meteorology and contribute to the characterization of Martian climate dynamics.

Mapping of phyllosilicates NW of Argyre basin (Mars) with Mars Express/HRSC colour data

Mariana Encarnação (University of Coimbra)
Co-authors: Daniela Tirsch, Ernst Hauber, Vidhya Rangarajan, Pedro Machado, Nuno Peixinho
Poster

The study of Martian mineralogy provides valuable insights into its geological history and environmental conditions over time. One significant aspect of Martian mineralogy is the presence of Fe/Mg-phyllosilicates, which are clay minerals formed through the alteration of basaltic rocks in the presence of water. These minerals are considered potential indicators of past habitable environments due to their association with aqueous processes. Remote sensing techniques, such as imaging and spectroscopy, have been instrumental in identifying and mapping phyllosilicates on Mars. Instruments onboard orbiters, such as the Mars Express and Mars Reconnaissance Orbiter (MRO), have detected these minerals in various regions, including ancient terrains and impact craters. In this study, we used data from the High Resolution Stereo Camera (HRSC) onboard the Mars Express to study the region located in the northwestern part of the Argyre basin. This region is of interest due to its complex geology and the presence of diverse geological units, including ancient terrains and impact-related features. The goal is to identify and characterise areas of interest that exhibit signs of phyllosilicate presence. We employed the red, green, and blue colour data obtained from the HRSC sensor to perform a preliminary mapping of surface materials in the study area.

The RGB composites allowed us to visualise variations in surface composition and identify regions with distinct spectral signatures that could indicate the presence of phyllosilicates. This mapping effort will guide the selection of specific targets for subsequent spectral analysis using near-infrared (NIR) data from instruments like the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard MRO. The combination of HRSC colour data and NIR spectroscopy enhances our ability to identify and characterise phyllosilicates and improve our understanding of the region's geological and aqueous history.

Probing the Atmosphere of WASP-76 b and WASP-178 b with High-Resolution Transmission Spectroscopy

Margarida Ferreira (Institute of Astrophysics and Space Sciences)
Co-authors: Pedro Machado, Olivier Demangeon
Poster

Transmission spectroscopy has proven to be a powerful tool for probing the atmosphere of transiting exoplanets. This technique has enabled the detection of a wide range of atomic and molecular species, offering valuable insights into the chemical composition of distant worlds. Moreover, retrieval of transmission spectra also reveals clues about atmospheric dynamics, wind patterns, and even the potential for biosignatures. In this talk, we focus on the atmospheric characterization of two of the most well-studied ultra-hot Jupiters (UHJ) to date: WASP-76 b and WASP-178 b. Living in extreme environments, with dayside temperatures exceeding 2000 K, these exoplanets provide unique laboratories for exploring their chemical composition. This study relies on the retrieval of high-resolution transmission spectra, using ESPRESSO spectrograph of ESO's Very Large Telescope (VLT) in Chile. Initially, visible absorption lines from H I and Na I were detected on both exoplanets. We were also able to confirm the detection of Ca II, Li I, and Mg I, through the narrow-band technique, on WASP-76 b. Furthermore, the cross-correlation technique was applied to detect additional spectral lines, including Fe I on both UHJ, as well as Ba II, Cr I, Mn I, and V I on WASP-76 b, and Mg I and Fe II on WASP-178 b.

Analysis of NIR activity indices for exoplanet detection and characterization

Telmo Monteiro (Faculdade de Ciências da Universidade do Porto (FCUP); Instituto de Astrofísica e Ciências do Espaço (IA-CAUP))
Co-authors: João Gomes da Silva (IA/CAUP); Elisa Delgado Mena (CAB, Spain); Nuno C. Santos (FCUP, IA/CAUP)
Poster

Stellar variability can impact planetary signals detected via the RV method. This is often addressed by tracking spectral lines sensitive to magnetic or/and temperature changes in the stellar atmosphere. With the growing use of NIR instruments like NIRPS, understanding NIR activity indicators is crucial, as their sensitivity may vary with stellar properties. We performed an in-depth analysis of 18 NIR activity lines in 20 M and K NIRPS-GTO stars to identify the best indicators for tracking stellar variability across different stellar characteris-

tics, using simultaneous observations with HARPS and NIRPS high-resolution spectrographs. Effective temperature, metallicity, pEW(Hα) and rotation periods were compiled for all stars. ACTIN was used to extract activity indices based on the Hα and Na I lines in the visual range. These, along with the FWHM of NIRPS CCF, served as anchors for activity level and variability. Activity indices were extracted from the 18 NIR lines and compared across stellar parameters using Spearman correlations with the anchor indices and GLS periodograms to recover the stellar rotation period. We found that a 0.6 Å central bandpass for Hα is optimal for both M and FGK stars. No single NIR indicator consistently traced activity across all stars, but several were effective for specific stellar parameter and observational ranges. Thus, the best approach is to select the optimal indicator case by case, with individual bandpass optimization, although this limits generalization. Additionally, we developed AMATERASU, a tool for easy extraction of pseudo-equivalent width-based activity indices with varying central bandpasses. AMATERASU generates activity index time series and uses GLS periodograms to identify periods close to user-defined inputs. This work provides a systematic analysis of the activity sensitivity of new and previously studied NIR lines and introduces a new tool to support stellar activity tracking both in the NIR and visual regimes.

Towards Achieving cm/s RV Precision with a New Line-by-Line code

Carmen San Nicolás Martínez (Faculdade de Ciências da Universidade do Porto (FCUP); Instituto de Astrofísica e Ciências do Espaço (IA-CAUP))
Co-authors: Nuno C. Santos, Vardan Adibekyan, André M. Silva, Khaled Al Moulla
Poster

The radial velocity (RV) method has confirmed over a thousand exoplanets, yet detecting Earth-like planets around Sun-like stars remains a major challenge. The expected RV signal of an Earth analogue (~9 cm/s) is easily masked and mimicked by stellar activity. Achieving the required precision demands innovative approaches to isolate and mitigate these effects. We present a new line-by-line (LBL) RV extraction code designed to reach this level of precision, which unlike other methods, does not require a reference spectrum/template. Our method builds on the ARES code to automatically detect absorption lines and fit Gaussian profiles to each one, extracting line parameters such as central wavelength, full width at half maximum (FWHM), and depth across time-series spectra. By computing the RV contribution of each line individually and statistically combining them, we obtain highly precise RV measurements. Additionally, this approach enables the identification of lines affected by stellar activity to various degrees, laying the groundwork for the creation of optimized spectral line lists. We demonstrate the performance of the method using ESPRESSO observations of the G-type star HD102365, showing that our LBL approach reaches a RV precision comparable to, or even surpassing, that of previous techniques.

Session 5 - Stars

Understanding Stars

Margarida Cunha (Instituto de Astrofísica e Ciências do Espaço)
Overview Talk

The past decade has brought a revolution in our understanding of stars, ranging from the processes that govern their formation, to the physics operating in their interiors, and their evolution toward the final stages of their lives. This progress has been driven by a new generation of space missions delivering ultra-precise photometry and astrometry, alongside cutting-edge ground-based facilities. In this talk, I will present some of the major recent advances in stellar physics, highlight key contributions led by Portuguese researchers, and discuss the major breakthroughs anticipated from forthcoming observational facilities.

Advancing Solar Magnetic Field Modeling

Carlos António (Instituto de Astrofísica e Ciências do Espaço, Universidade de Coimbra, Faculdade de Ciências e Tecnologia)
Co-authors: Ricardo Gafeira; Iulia Chifu
Contributed Talk

Energetic events such as solar flares and coronal mass ejections (CMEs), which can lead to solar storms, are driven by the coronal magnetic field (CMF), whose structure and evolution remain not fully understood. When Earth-directed, these storms can trigger auroras - as observed in Portugal in 2024 - but also pose serious risks to radio communications, GPS systems, power grids, and satellite infrastructure. Under certain conditions, Extreme Ultraviolet (EUV) observations reveal useful information about the 3D geometry of some magnetic field lines, as the emitting plasma is "frozen into" the magnetic field, though they do not provide measurements of the magnetic field. Unlike the solar surface - the photosphere - where the magnetic field can be measured via spectropolarimetry, this is generally not achievable in the typically force-free corona, due to the faintness and thermal broadening of spectral lines. As a result, extrapolation methods are used to infer the coronal magnetic field from routine photospheric measurements. The most widely used model, the Potential Field Source Surface (PFSS), is fast and computationally efficient, but it calculates a current-free, minimal-energy coronal field using the low measurement uncertainty photospheric radial magnetic field component. This limits its accuracy in active regions, where magnetic free energy - critical for flares and CMEs - is stored. More advanced, state-of-the-art Non-linear Force-Free Field (NLFFF) models allow for electric currents and, therefore, free energy, leading to greater accuracy, but they are computationally intensive and highly sensitive to data quality. We developed a significantly faster Python code built upon a functional optimization framework previously proposed and implemented by our team. In this new version, we introduce a three-term functional that simultaneously minimizes: (1) the angle between the magnetic field and the tangents to observed EUV loops, (2) the divergence of the magnetic field, and (3) the Lorentz force. Including the Lorentz-force term enables our method to control the degree of force-freeness, an essential physical property typically accessible only to the more computationally demanding NLFFF models. By minimizing the proposed functional, we derive the perturbations that are iteratively applied to the original PFSS solution. The resulting magnetic field represents a trade-off between alignment with EUV loops, solenoidality (divergence-freeness), and force-freeness, yielding a more physically realistic configuration. This approach retains the computational efficiency of PFSS while significantly improving the physical consistency of the solution. Validation against EUV observations confirms the method's ability to produce magnetic field solutions that are more accurate and observationally constrained, providing a new, efficient, and reliable tool for coronal magnetic field studies.

Numerical Relativity Simulations of Dark Matter Admixed Binary Neutron Stars

Hannes Rüter (CENTRA, Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa)
Co-authors: Edoardo Giangrandi, Nina Kunert, Mattia Emma, Adrian Abac, Ananya Adhikari, Tim Dietrich, Violetta Sagun, Wolfgang Tichy, Constança Providência
Contributed Talk

Binary neutron star mergers provide insight into strong-field gravity and the properties of ultra-dense nuclear matter. These events offer the potential to search for signatures of physics beyond the standard model, including dark matter. We present the first numerical-relativity simulations of binary neutron star mergers admixed with dark matter, based on constraint-solved initial data. Modeling dark matter as a non-interacting fermionic gas, we investigate the impact of varying dark matter fractions and particle masses on the merger dynamics, ejecta mass, post-merger remnant properties, and the emitted gravitational waves. Our simulations suggest that the dark matter morphology - a dense core or a diluted halo - may alter the merger outcome. Scenarios with a dark matter core tend to exhibit a higher probability of prompt collapse, while those with a dark matter halo develop a common envelope, embedding the whole binary.

Exploring the magnetic fields of Ap stars with TESS

Inês Rolo (CAUP)
Co-authors: Pedro Avelino, Margarida Cunha, Ângela Santos
Contributed Talk

Chemically peculiar A-type (Ap) stars are known for their strong magnetic fields, but only a small fraction (∼5.5%) exhibit pulsations. To date, the reason for this is poorly understood, as the study of these stars has been greatly challenged by their rarity. We present a new algorithm designed to explore TESS data products, specifically 200-sec cadence Full Frame Images as well as 120-sec, and 20-sec cadence light curves, to look for stellar oscillations. This tool is capable of identifying and classifying various classes of stellar pulsators, roAp

stars, δ-Scuti stars, and other classical pulsators, as well as non-pulsating Ap (noAp) stars. Leveraging this code we construct, for the first time, a sample of noAp stars with stellar properties consistent with those of the 100 currently known roAp stars. Using data from Gaia we homogeneously derive several seismic and non-seismic parameters for these samples. By comparing these two samples, our goal is to investigate whether there are systematic physical differences that can explain why so few Ap stars pulsate. Among the parameters we investigate for both samples is the magnetic field, which is known to play a key role in the excitation of pulsations in Ap stars. We start by numerically constraining the dipolar magnetic field strength (B_d) using two observable magnetic quantities: the mean longitudinal field and the mean magnetic field modulus. Our method improves upon existing techniques by providing tighter constraints on Bd even with limited data. Our results indicate that roAp stars showing high radial orders and pulsation frequencies above the acoustic cut-off frequency tend to possess lower dipolar field strengths. Our results support theoretical predictions suggesting that such high-frequency oscillations may be excited by turbulent pressure rather than the classical opacity (k) mechanism. This finding puts us one step closer to understanding the physical conditions that govern pulsation excitation in Ap stars.

Probing Dense Matter Through Neutron Stars: Machine Learning Insights on the Equation of State

Tuhin Malik (CFisUC, Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal)
Co-authors: João Cartaxo, Helena Pais, Constança Providência, Hiranmaya Mishra
Contributed Talk

The equation of state (EOS) of ultra-dense matter remains one of the most challenging problems in nuclear astrophysics, with neutron stars serving as unique cosmic laboratories for exploring matter under extreme conditions. This talk presents recent advances in constraining the neutron star EOS through innovative approaches combining Bayesian inference, machine learning techniques, and multi-messenger observations. I will discuss how symbolic regression and neural network methods reveal robust relationships between neutron star observables - including mass, radius, tidal deformability, and f-mode oscillation frequencies - and the underlying nuclear matter properties. Our analysis spans diverse EOS models, from relativistic mean-field approaches to agnostic meta-models, providing model-independent constraints on dense matter behavior. Key findings include strong correlations between maximum neutron star mass and specific thermodynamic conditions, and new constraints from proto-neutron star evolution on the presence of exotic matter. The presentation will highlight practical applications of these machine learning-derived relations, demonstrating how they significantly accelerate Bayesian inference calculations while maintaining accuracy. These methods offer new pathways for extracting nuclear matter properties directly from gravitational wave observations and X-ray timing data, particularly relevant as Portugal expands its role in international astronomical collaborations through next-generation observatories.

The SXS Collaboration's third catalog of binary black hole simulations

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Poster

We present a major update to the Simulating eXtreme Spacetimes (SXS) Collaboration's catalog of binary black hole simulations. Using highly efficient spectral methods implemented in the Spectral Einstein Code (SpEC), we have nearly doubled the total number of binary configurations from 2,018 to 3,756. The catalog now densely covers the parameter space with precessing simulations up to mass ratio q = 8 and dimensionless spins up to || 0.8 with near-zero eccentricity. The catalog also includes some simulations at higher mass ratios with moderate spin and more than 250 eccentric simulations. The full catalog is publicly available through the sxs Python package and at https://data.black-holes.org .

On the discrepancy between modelled and interferometric radii of K-type stars using asteroseismology

Rúben António Ribeiro Costa (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Tiago Campante; Mário João P. F. G. Monteiro; Morgan Deal
Poster

In K-type stars, with masses from 0.6 to 0.9 solar masses and effective temperature from 3900 K to 5300 K, a systematic discrepancy exists between the values for the modelled and interferometric radii. Stellar models tend to underestimate the radius by about 3-5%, while also overestimating the effective temperature by approximately 5%. In our work, we will analyse this discrepancy for K-type stars with stellar oscillations, whose measurement has only been recently possible through advanced spectrographs such as ESPRESSO and Keck Planet Finder. Our sample will include the stars œµ Indi, œÉ Draconis, HD 219134, HD 131977 and HD 191408. To determine the properties of our sample of stars, we will use a large grid of stellar models calculated using MESA, with asteroseismic modes computed by GYRE. We then perform model optimization using AIMS, comparing our grid of models to the asteroseismic and interferometric observational constraints of each star. One suggested solution for mitigating this discrepancy is through the calibration of the mixing length pa-

rameter, which controls the efficiency of energy transport by convection, and that has a direct impact on the radius. That is why in our forward modelling procedure the mixing length is a free parameter, allowing us to obtain mixing length values different from the Sun, estimating the impact it has on the discrepancy between the modelled and interferometric radius.

Shedding light on the complexities of stellar rotation

Juliana Amaral (Faculty of Science, University of Porto; CAUP)
Co-authors: Ângela R. G. Santos; Margarida M. S. Cunha; Rafael A. García
Poster

Magnetic activity is a key factor in stellar evolution and exoplanetary research and is driven by differential rotation. Average stellar rotation periods are derived from light curves that show brightness variations due to dark starspots. However, separating contributions from spots at different latitudes to measure differential rotation remains challenging. This study aims to develop methods to constrain differential rotation using peak height ratios, improving our understanding of stellar magnetism. We use numerical simulations to model the spot behavior on the stellar surface, obtaining light curves and periodograms. We start with simple light curves featuring one spot with a constant area and one with a variable area, gradually increasing the complexity by adding more spots and varying their properties. To study differential rotation, we apply the peak height ratio technique, which compares the heights of the first and second harmonics of the rotation signal. This method not only determines whether the equator rotates faster or slower than the poles but also quantifies the amplitude of this rotational difference. By comparing results, we assess the technique"s sensitivity to differential rotation with different spot configurations. Our results show that variations in spot area affect the peak height ratios, but the impact is minimal for 1-spot simulations. In more complex 2-spot simulations, the effect becomes more significant, suggesting a stronger dependence on spot distribution. Nevertheless, the recovery of rotation parameters in the 2-spot simulations was satisfactory, demonstrating that the method can still yield reliable estimates despite increased complexity. This work is a key step in obtaining reliable differential rotation estimates for stars observed by NASA's Kepler and ESA's PLATO missions, advancing our understanding of stellar dynamo processes. Key words: stars, rotation, starspots, activity

A Flexible Relativistic Mean-Field Approach to the Neutron Star Equation of State

João Cartaxo (CFisUC, Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal)
Co-authors: Tuhin Malik
Poster

Traditional relativistic mean-field (RMF) models for the neutron star equation of state (EOS) rely on pre-specified energy density functionals, which can limit their flexibility in capturing the full range of dense matter behavior. This work presents a novel RMF-based framework

that circumvents this limitation by constructing the EOS without prior specification of the functional form, achieving flexibility comparable to agnostic and meta-model approaches while maintaining the physical foundations of RMF theory. Our method employs a data-driven parameterization that allows the model to adapt to observational constraints from neutron star masses, radii, and gravitational wave observations, while respecting fundamental principles of nuclear physics. The approach bridges the gap between phenomenological flexibility and microscopic consistency, enabling systematic exploration of the dense matter parameter space. We demonstrate how this framework can accommodate diverse astrophysical constraints and provide robust predictions for neutron star properties across the full mass range. This new methodology offers a promising path for EOS modeling that combines the interpretability of RMF models with the adaptability required for modern multi-messenger astronomy, providing a valuable tool for constraining the properties of matter at extreme densities.

Neural posterior estimation of the Equation of state of neutron stars

Valéria Carvalho (Universidade de Coimbra)
Co-authors: Márcio Ferreira, Constança Providência, Michal Bejger
Poster

The equation of state (EoS) of neutron star matter encodes the relationship between pressure and density at supranuclear densities, fundamentally governing the star's structure and observable macroscopic properties, such as mass, radius, and tidal deformability. I In this work, we apply Neural Posterior Estimation (NPE) with conditional normalizing flows to infer the EoS from synthetic observational data. We consider two model-agnostic EoS families—polytropic and Gaussian process-based—and train our models on mock mass-radius and mass-radius–tidal deformability datasets with varying noise levels. We evaluate reconstruction performance in terms of pressure and squared speed of sound across baryonic densities, and quantify the impact of including tidal deformability information. Our results demonstrate that tidal measurements significantly reduce inference uncertainty, particularly for pressure, and confirm that NPE-based models can accurately capture physical constraints. The framework also generalizes well to previously unseen EoS parametrizations, highlighting the robustness of the approach for future multimessenger astrophysical analyses.

The JWST view of proplyd HST10: gas, dust and PAHs

Sílvia Vicente (Instituto de Astrofísica e Ciências do Espaço (IA))
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Poster

What is the composition, and hence reservoir, in dust, gas and polycyclic aromatic hydrocarbon molecules (PAHs) in a typical externally illuminated disk (proplyd)? What is the

thermo-chemical structure of a proplyd Photodissociation Region (PDR)? How does external irradiation affect the process of planet formation in these disks? And how their properties differ from those of disks found in more quiescent environments, such as Taurus-Auriga? These questions are addressed in our Cycle2 program GO 4332 (PI: S. Vicente) consisting in a JWST deep observational study of an EUV+FUV externally illuminated protoplanetary disk (proplyd) found in the Orion Nebula Cluster (ONC) using the IFU mode of NIRSpec and MIRI-MRS. The JWST observations spatially resolve the disk, neutral cocoon and ionization front simultaneously over the 0.9 - 11.7 micron spectral range, providing key line, continuum and PAHs diagnostics to trace the physical conditions, the chemical composition and abundances under the effect of the external FUV-radiation. It is the FUV radiation that changes the thermo-chemical structure of the disk, creates the PDR and sets the mass-loss rate through photoevaporation. By comparing our results to those of protoplanetary disks (TTauris) found in nearby low-mass star forming regions, one can start to assess the real effects of a FUV-dominant environment on protoplanetary disk evolution and planet formation. In this talk I will introduce program GO 4332 and I will show the observational results of the JWST MIRI and NIRSpec data in gas, dust and PAHs. I will also present the results of our preliminary analysis using 2D modelling.

Dual-Purpose Use of the Santa Maria VGOS Antenna for Geodetic VLBI and Methanol Maser Observations

Valente Cuambe (RAEGE-Az)
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Poster

We present the technical specifications and scientific capabilities of the Santa Maria VGOS antenna. This 13.2-meter radio telescope is part of the RAEGE (Rede Atlântica de Estações Geodinâmicas e Espaciais) network in the Azores. While primarily designed for geodetic Very Long Baseline Interferometry (VLBI), we demonstrate its potential for astronomical applications in single-dish mode, particularly for observing methanol masers at 6.68 GHz and 12.18 GHz. The technical description includes the broadband cryogenic receiver, backend system, and observing strategy, which enable high-sensitivity and high-resolution observations. We report the detection of methanol maser emission from sources including G009.621+0.196, G109.871+2.114, G111.542+0.777, G133.947+1.064, and G134.029+1.072, with flux densities comparable to or within the range of previous studies. By comparing these results with those from large interferometric arrays (e.g., VLA, EVN) and single-dish surveys (e.g., MMB, M2O), we highlight the single-dish VGOS antenna's suitability for long-term maser monitoring.

Session 6 - Astrobiology

Origin and Search for Life in the Solar System

Zita Martins (Instituto Superior Técnico)
Overview Talk

Astrobiology is an interdisciplinary research area that investigates the origin and evolution of life in the Universe. The origin of life would have required water and organic molecules to make up the basic unit of life, i.e., the cell. These could have been provided by comets, and meteorites to the Earth between 4.56 to 3.8 billion years ago, or formed at hydrothermal vents. While the Earth is currently the only location we know that has life forms, life may have also arisen elsewhere in the solar system, including Mars and the icy moons of Jupiter and Saturn (e.g., Europe and Enceladus). In this presentation I will give an overview of the Astrobiology research area, and also show the findings of the Expert Committee of ESA for the Large-class (L4) space mission covering the science theme "Moons of the Giant Planets", and how it will address topics such as habitability, prebiotic chemistry, and biosignatures.

The Photochemistry of Amino Acids Produced on the Polar Cryovolcanic Regions of Titan

Zita Martins (Instituto Superior Técnico)
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Contributed Talk

Transient liquid-water environments on Titan's surface shall break Titan's atmospheric macromolecules into prebiotic molecules [1,2]. NASA"s upcoming Dragonfly mission will investigate the extent of that prebiotic chemistry on Titan"s surface and search for biosignatures of putative subsequent biological-like metabolic processes [3]. On its search, however, the Dragonfly lander may not probe cryovolcanic regions, whose prebiotic potential has been repeatedly demonstrated [4]; cryovolcanic features are most common on the poles [5], whereas Dragonfly will explore equatorial locations. We discuss the possibility of Dragonfly sampling the prebiotic molecules produced in the polar cryovolcanic regions of this Saturnian moon. We suggest a two-step pole-to-equator transportation scenario: first, the exsolution of ocean gases from the cryolavas would encapsulate the prebiotic molecules in water-ammonia icy aerosols [6]; second, Titan's Hadley circulation would transport the icy aerosols from the summer pole to the other latitudes, of which the equator, where these would have accumulated and be prone to detection by Dragonfly. The biggest obstacle to such transportation is the high-altitude of the circulation upper branch, up to Titan's mesosphere. We experimentally evaluated whether the photodegradation expected during the transportation hinders the detectability of glycine and alanine. To measure the photodegradation rates of glycine and alanine, we adapted an experimental concept previously explored to study the photodegradation of organic molecules in space and planetary conditions [7]. To extrapolate the measured degradation rates to Titan's mesosphere, we modeled the latter. Comparing the calculated half-lives on Titan's mesosphere to the expected transportation timescale, we conclude that the two amino acids can survive the pole-to-equator transportation; we suggest that Dragonfly may find prebiotic molecules, in the equatorial organic dunes, seeded from the polar cryovolcanic regions of Titan [10]. Further, the irradiation of a 1:1 mixture sample of alanine and glycine (characterized in ref. [10]) led to an unexpected ten-fold increase in the photodegradation of glycine compared to the pure glycine sample [10]. Through quantum chemistry computational methods, we identified the change in environment polarity as the cause to the enhanced photodegradation of glycine.

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Hydrothermal Analogues to the Icy Moons of the Solar System

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Contributed Talk

Hydrothermal vents are key environments for origin-of-life research due to their strong geochemical gradients, dynamic physicochemical conditions, and active mineral-fluid interactions. While alkaline systems have received significant attention for their role in promoting protocell formation, vents with mildly acidic to neutral pH (5–8) can also generate chemical gradients capable of supporting prebiotic chemistry [1,2]. Earth-based hydrothermal systems can be considered analogues to putative subsurface environments in icy ocean extraterrestrial worlds such as Enceladus and Europa [3,4]. This study examines hydrothermal and fumarolic sites across the Azores archipelago, including coastal (6–8m) and shallow water (25–40m) systems. Liquid, gas, and sediment samples were collected and analyzed to assess their chemical compositions. Trace elements in sediments and fluids were quantified using inductively coupled plasma mass spectrometry (ICP-MS) following sequential extraction and acid digestion. Anions (Cl, NO, SO^{2}) were identified via ion exchange chromatography. Gas samples were examined using gas and ion chromatography, potentiometric and colorimetric titration techniques. Data revealed the presence of several trace elements, including species such as As, Cd, Pb, Hg, and U, as well as biologically relevant elements like Mo, Se, and Sr, albeit in low concentrations. Chloride and sulfate levels were consistent with those of marine and freshwater environments, while nitrate was undetectable [5]. Gas analyses showed dominance of HO and CO, mirroring plume compositions observed on Enceladus, along with the presence of Ar, O, CH, He, HS, and N, which are similar to the subaerial degassing emissions associated with the active Azorean volcanoes [6–11]. The pH of vent fluids and adjacent waters ranged from 6.9 to 8.0, overlapping with modeled and observed values for the subsurface ocean on Enceladus (7.9–12) and Europa (2.6–8.4) [9,11–14]. Although no consistent trend was observed in trace elemental, the concentrations of Cl (475mM) and SO^{2} (23mM) in the Azorean systems were notably higher for chloride and lower for sulfate than those estimated for Enceladus and Europa (Cl: 200–250mM; SO^{2}: <1–40mM). These concentrations, in conjunction with similar pH ranges and gas profiles, emphasize the relevance of Azorean hydrothermal systems as analogues for geochemical processes potentially occurring in icy moons [3,4,9–11,15–17]. These results highlight the value of terrestrial hydrothermal systems for astrobiological research, providing accessible locations to investigate chemical environments that could originate and foster life beyond Earth. Acknowledgements: The financial support of Fundação para a Ciência e a Tecnologia (FCT) is acknowledged by Z.M. through project ORIGINS (2022.05284.PTDC), and by J.M.O.-B. through PhD fellowship 2024.01442.BD. AC via CEEC contract CEECIND/00101/2021 (https://doi.org/10.54499/2021.00101.CEECIND/CP1669/CT0001) and FCT, I.P., under the project UIDB/05634/2025 and UIDP/05634/2025 [1] Sojo, V. et al. Astrobiology, 16:181–197 (2016).[2] Lane, N. BioEssays, 39:1600217 (2017).[3] Deamer, D. Damer, B. Astrobiology, 17:834–839 (2017).[4] Cable, M. et al. The Planetary Science Journal, 2:132 (2021). [5] Diehl, A. Bach, W. Geochemistry, Geophysics, Geosystems, 21:e2020GC009385 (2020). [6] Moreno, L. et al. Chemical composition of submarine degassing areas in São Miguel Island (Azores archipelago). (Unpublished).[7] Matias, D. et al. Journal of Volcanology and Geothermal Research, 450:108076 (2024). [8] Fox-Powell, M. G. Cousins, C. R. J. Geophys. Res. Planets, 126:e2020JE006628 (2021). [9] Glein, C. R. et al. Geochim. Cosmochim. Acta, 162:202–219 (2015). [10] Hand, K. P. Chyba, C. F. Icarus, 189:424–438 (2007). [11] Pasek, M. A. Greenberg, R. Astrobiology, 12:151–159 (2012). [12] Johnson, P. V. et al. Icarus, 321:857–865 (2019). [13] Schenk, P. M. et al. Enceladus and the Icy Moons of Saturn, University of Arizona Press (2018). [14] Fifer, L. M. et al. Planetary Science Journal, 3:191 (2022). [15] Postberg, F. et al. Nature, 618:489–493 (2023). [16] Trumbo, S. K. et al. Science Advances, 5:eaaw7123 (2019). [17] Trinh, K. T. et al. Science Advances, 9:eadf3955 (2023).

Fiber Optic Chemical Sensors for the In-Situ Characterization of Icy Moons

Zita Martins (Instituto Superior Técnico)
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Poster

The suitability of fiber optic sensors [1] for space missions led to their implementation in the JUICE magnetometer (J-MAG), on the recently launched JUICE mission [2]. Still, fiber optic sensors dedicated to chemical characterization – named fiber optic chemical sensors, FOCS [3,4] – have yet to be explored in space applications. We argue that FOCS should complement the new generation of in-situ chemical characterization techniques for extraterrestrial environments [5]. To support it, we are developing FOCS capable of detecting hydrocarbons of interest in Titan's hydrocarbon lakes. These sensors address both the limitations of mass spectrometry in differentiating between hydrocarbon isomers and the low specificity of infrared spectroscopy. We have simulated the detection of butadiene (C4H6). To address the slow reaction kinetics expected at Titan's low temperatures, our butadiene sensors are based on click reactions enabled by the Carboni-Lindsey mechanism [6]. It consists of a fast and selective reaction between a 1,2,4,5-tetrazine molecule and an olefin (butadiene, in our application), producing as its sole by-product N2, the major component of Titan's atmosphere. We uncovered a tetrazine derivative which reacts with butadiene to form a high-emissivity product, generating an off-on fluorescence signal. Further, pH measurements performed by FOCS have demonstrated high sensitivity [3]. We are developing pH FOCS to benchmark this technology against alternative strategies to quantify the pH of extraterrestrial aqueous bodies, such as the alkaline subsurface ocean of Enceladus [7]. So far, the immobilization of known pH indicators in polymeric membranes demonstrated negligible leaching in aqueous solutions and fast responses to ammonia-induced pH variations.

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Session 7 - Instrumentation

Instrumentation to Space

Alexandre Cabral (Instituto de Astrofísica e Ciências do Espaço)
Overview Talk

Light is a fundamental tool in understanding our universe. With the most modern telescopes and instruments capable of analysing the light that reaches us from other Astronomical objects, it has been possible in recent years to make considerable progress not only in astrophysics but also in the technology that supports its instruments. In this talk, we will explore the involvement of the Institute of Astrophysics and Space Sciences in ESA and ESO projects, presenting some examples where the demands of astronomy are driving the development of state-of-the-art space instrumentation.

Portuguese Space Instrumentation for High-Energy

Rui Curado Silva (LIP and Dep of Physics UC)
Focus Talk

High-energy astrophysics has gained renewed interest following the observation of simultaneous signals: a gravitational wave (GW) detected by the LIGO and Virgo ground-based observatories, and a gamma-ray burst (GRB) observed by high-energy space telescopes—both generated by a neutron star merger—boosting the field of multi-messenger astrophysics. Furthermore, gamma-ray astrophysics reveals the non-thermal Universe: cosmic accelerators, explosive nucleosynthesis, astrophysical jets, compact objects, and it probes deeply into cosmic engines. However, observational sensitivity in this domain is two orders of magnitude lower compared to other wavelengths. For the past two decades, Portuguese researchers have been actively involved in the development of space instrumentation for high-energy astrophysics, designing, building, and testing gas-based detectors, semiconductors, and scintillators with spectroscopic, imaging, time-variability, and polarimetric capabilities. Portuguese contributions have been integrated into ESA's XIPE mission (later adopted by NASA as IXPE), early versions of the ATHENA mission, NASA's AMEGO mission proposal, and ESA's M7 pre-selected ASTROGAM mission proposal. These contributions to medium- and large-class missions will be presented, along with space experiments such as GLOSS on board the ISS and THOR, which will fly on the maiden mission of ESA's new reusable vehicle, the Space Rider, scheduled for launch in 2027 and set to land on Santa Maria Island in the Azores.

The Successful Integration of the ELP subsystem of the WSS/METIS for the ESO/ELT at the ELP Manufacturing Facility in Portugal

António Amorim (FCUL & LIP)
Co-authors: Mercedes Filho (FEUP & CENTRA), Miguel Esteves (FCUL), João Canais (FCUL & LIP), Paulo Garcia (FEUP & CENTRA)
Contributed Talk

The ELP (Elevation Platform) is the four-meter high, three ton, steel support subsystem of the WSS (Warm Support Structure) for METIS (Mid-Infrared ELT Imager and Spectrograph), a first-light instrument for the ESO-constructed ELT (Extremely Large Telescope). Due to its complexity and large-scale structure, integration of the WSS has been planned in three phases, the first of which is the manufacturing and assembly of the ELP at the Portuguese manufacturer (Cunhol). In this presentation we will address the successful integration procedure, the encountered obstacles, the solutions and the measurement strategy utilized to verify built-for dimensions. The next steps for the ELP are the Acceptance Review by ESO and the METIS Consortium, followed by the shipment to Leiden, where the ELP will be integrated with the rest of the METIS system.

THOR-SR on Board the Space Rider: Monitoring Space Radiation and Space Weather in LEO

Cristiana Francisco (Centre for Earth and Space Research of the University of Coimbra (CITEUC), Portugal. Laboratory of Instrumentation and Experimental Particle Physics (LIP), Portugal.)
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Contributed Talk

The TGF and High-energy astrophysics Observatory for gamma-Rays on board the Space Rider (THOR-SR) is an upcoming ESA mission designed to monitor the radiation environment in Low Earth Orbit (LEO) and study its relation to Space Weather (SW) phenomena. THOR-SR's payload includes a CdTe gamma-ray detector and a Si Particle Tracker, based on the Timepix2/Timepix3 ASIC chips, configured for precise charged particle tracking. THOR-SR will operate during a two-month flight aboard the Space Rider platform, providing high-resolution measurements of trapped radiation, galactic cosmic rays, and solar energetic particles. GEANT4-based simulations of detector performance, development of a data selection pipeline for machine learning analysis, and strategies to correlate in-flight measurements with geomagnetic and solar activity indicators, aim to contribute to a more detailed understanding of the radiation environment in LEO and to enhance the interpretation of data for SW monitoring and spacecraft design.

A quest to detect a star's velocity - Radial velocity extraction and associated challenges

André M. Silva (Instituto de Astrofísica e Ciências do Espaço (IA-CAUP))
Co-authors: Nuno Santos, Alexandre Cabral, Manuel Abreu, Manuel Monteiro, Inês Leite, Bachar Wehbe, David Alves, Ricardo Gafeira, Jorge Martins, Pedro Moreno, William Dethier, António Oliveira, Ricardo Clara, Jennifer Peralta, Alba Barka, Khaled al Moulla, Carmen Martinéz
Contributed Talk

One of the boldest challenges of present-day astrophysics is to find and characterize other Earths: rocky planets that are capable of sustaining liquid water on their surface over long periods of time. One of the most prolific extra-solar planet discovery methods is radial velocities (RV). However, the identification of Earth-like planets faces significant challenges due to the small amplitudes of such signals and the difficulties introduced by two factors: i) Earth's atmosphere; and ii) the stellar surface presenting temporal and spatial variability. The level of precision needed to detect Earth-like planets orbiting other suns thus motivated new developments in both instrumentation (e.g. ESPRESSO) and data analysis. It was in this context that the s-BART (Silva+2022) algorithm was developed. At its core, s-BART is a Bayesian implementation of the widely used template-matching algorithm, extracting RVs through a comparison of stellar spectra with a stellar model. To tackle the contamination of stellar activity, an assumption of achromaticity is imposed - a RV common to all wavelengths is used to describe the misalignment between model and data. In this talk, we will also present an overview of the results that this algorithm provides for multiple state-of-the-art spectrographs, highlighting some of its discoveries. Lastly, we reveal a previously unidentified systematic bias in RV extraction when using template-matching (TM) algorithms with stellar models constructed from observations that were collected within a short time-span. The presence of this bias is shown in two template matching pipelines, present in the data of multiple state-of-the-art spectrographs, and it has different amplitudes for different stars. We hypothesize that contamination from microtelluric features is the likely root cause of this effect, which could have implications for high-precision RV studies, particularly in short-timescale observing campaigns.

ANDES, the high-resolution spectrograph for the ELT: The Front-End and its seeing limited arms

Bachar Wehbe (Institute of Astrophysics and Space Sciences)
Co-authors: Alexandre Cabral, Manuel Abreu, Ricardo Clara, Antonio Oliveira, Matteo Aliverti, Nuno Santos
Contributed Talk

The first generation of ELT instruments includes an optical-infrared high-resolution spectrograph, indicated as ELT-HIRES and recently christened ANDES (ArmazoNes high Dispersion Echelle Spectrograph). ANDES consists of three fibre-fed spectrographs ([U]BV, RIZ, YJH) providing a spectral resolution of $\sim 100{,}000$ with a minimum simultaneous wavelength coverage of 0.4–1.8 μm with the goal of extending it to 0.35–2.4 μm with the addition of an U

arm to the BV spectrograph and a separate K band spectrograph. It operates both in seeing- and diffraction-limited conditions and the fibre-link allows several interchangeable observing modes including a single conjugated adaptive optics module and a small diffraction-limited integral field unit in the NIR. Modularity and fibre-feeding allows ANDES to be placed partly on the ELT Nasmyth platform and partly in the Coudé room. ANDES has a wide range of groundbreaking science cases spanning nearly all areas of research in astrophysics and even fundamental physics. In this talk I will generally introduce ANDES and focus on its Front-End, the connection between the ELT focal plane and the spectrographs (through the fiber link). I will present the current design and focus on the seeing limited arms opt-mechanics.

Development of a CdTe Multiplanar Instrument

Duarte Rodrigues (Physics Department of the University of Coimbra)
Co-authors: Cristiana Francisco, Alexandre Trindade, André Neves, Fernando Pinheiro, Gabriel Falcão, João Campos, Jorge Maia, José Sousa, Mariana Letra, Miguel Ferreira, Pedro Carmo, Rui Curado Silva
Poster

Gamma-ray astronomy in the 0.2–100 MeV energy range offers direct observation of the most energetic and dynamic phenomena in the Universe, such as black holes, pulsars, gamma-ray bursts and active galactic nuclei. Gamma rays carry unique information from these internal cosmic accelerators, revealing hidden processes at lower energies. However, there are many associated observational challenges, so technological advances in the area provide many scientific benefits and opportunities. The TGF and High-energy astrophysics Observatory for gamma-Rays on-board Space Rider (THOR-SR) mission, developed by the i-Astro group Laboratório de Instrumentação e Física Experimental de Partículas (LIP) Coimbra, will be launched on the maiden flight of the "Space Rider". THOR-SR focuses on the 100 keV to 1 MeV energy range and performs spectroscopy, time variability measurements, imaging, and polarimetry of continuum and transient space gamma-ray sources. It will monitor terrestrial gamma-ray flashes (TGF) from Earth and the space radiation environment in low Earth orbit. This project, part of the THOR-SR mission, was responsible for performing tests using the Gamma Tracker Array (GAM) to reconstruct the position of gamma-ray emission sources through Compton reconstruction. The Gamma Tracker Array (GAM), a semiconductor-based instrument composed of cadmium telluride (CdTe) detectors, was developed by ADVACAM. The prototype model consists of four stacked CdTe finger boards, each separated by a distance of 0.8 cm and made up of a matrix of 256 x 256 pixels. The flight model configuration will include three individual detection planes, each one with four finger boards horizontally aligned, arranged in a stack parallel configuration. Experimental tests were performed with the prototype configuration using radioactive sources of ^{57}Co, ^{133}Ba, ^{22}Na, and ^{137}Cs at on-axis incidence and at incidence angles of 5°, 30°, and 60°. The MEGAlib software was employed for data analysis and flight model simulations. The width of the reconstructed Compton cones and arcs is represented by the Angular Resolution Measure, which was used to quantify the system's angular resolution. The relationship between ARM fit parameters and the incident photon energy was also studied. Measurements were performed by changing the number of active detector planes, revealing that most of the events that occurred in the detector were in the same plane. In other words, there were relatively few events that had interactions in different planes. This implies that the number of planes used did not have a significant impact on the observed results. Notably, the obtained results confirm the possibility of performing Compton reconstruction of incident radioactive sources during flight, demonstrating the potential of the GAM detector for future space applications.

PoET, The Paranal solar ESPRESSO Telescope: Countdown to installation

Inês Leite (Instituto de Astrofísica e Ciências do Espaço, FC.UL)
Co-authors: Alexandre Cabral, Nuno Santos, André Silva, António Oliveira, Bachar Wehbe, David Alves, Jorge Martins, Khaled Al Moulla, Manuel Abreu, Manuel Monteiro, Pedro Moreno, Ricardo Clara, Ricardo Gafeira, William Dethier, Alba Barka, Carmen San Nicolás, Jennifer Peralta
Poster

There are currently some challenges imposed by stellar "noise" often associated with the discovery and characterization of exoplanets like Earth. Various physical processes occurring on the stellar photosphere modify stellar spectra, severely challenging the detection and characterization of low-mass planets. A detailed study of Sun can be used as a spectral proxy to a better understanding of the variable noise sources present in solar-type stars. By performing full integrations of the disk in combination with high resolution, spatially resolved smaller areas, acquired spectra will help in the identification of individual stellar features responsible for the observed spectral deformations. The Institute of Astrophysics and Space Sciences in Portugal is currently developing an instrument to approach this challenge, in conjunction with the high-resolution spectrograph ESPRESSO, in high and ultra-high modes (R ~140 000 to ~190 000, respectively). The Paranal solar ESPRESSO Telescope (PoET) has the requirement to perform simultaneous observations: disk-resolved, from 1 to 55 arcsecond, and disk-integrated, capturing the full disk of the Sun. To achieve this the instrument will have two dedicated telescopes with diameters of 600 millimetres and 75 millimetres, to map the Sun's surface through disk-resolved and disk integrated observations, respectively. In this presentation the current configuration for PoET will be showcased, as well as the future steps for its installation and commissioning at the Paranal observatory, in Chile.

Towards the miniaturization of cross-dispersed echelle spectrographs: Parametric modelling and trade-off analysis of three optical designs

Nuno M. Gonçalves (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Alexandre Cabral, Manuel Abreu
Poster

High-resolution (HR) spectroscopy plays a fundamental role in modern astronomy. Cross-dispersed echelle spectrographs (CDES) are at the forefront of HR spectroscopy for both ground- and space-based observatories. Currently, a wide range of science cases–from ex-

oplanet detection to solar characterization–require the capabilities of HR CDES. One constraint with this design typology is that the instruments are very bulky and complex. CDES come with a variety of optical designs, each tailored to specific scientific objectives and the observatory in which they are used. Based on their optical path, three major designs variations can be identified: the classic design, the double-pass, and the three-fold. The classic design is the original configuration; it was the first used in these instruments and remains the simplest to assemble. The double-pass design employs a single optical element as both the collimator and camera, enhancing the compactness of the system. Finally, the three-fold design–a white-pupil configuration that represents the current state of the art in ground-based observatories–uses a parabolic mirror to fold the beam three times. This approach enables a more compact design and allows for smaller aperture cross-dispersers and cameras, thanks to the white-pupil property. Each of these designs contributes differently in terms of area footprint, spectral power, and efficiency. However, no systematic analysis has been done to quantify the contributions of these characteristics across the different configurations. In this work, we propose a parametrization of the mathematical models for the three designs. This approach allows us to quantify the impact of each design parameter on spectral power, area footprint, and efficiency. Ultimately, this parametrization enables a trade-off analysis between the designs using these criteria, helping to identify the optimal optical configuration for specific needs in terms of space, spectral power and efficiency to be applied in both space- and ground-based observatories.

A seeing measurement device for solar observations

Ana Sofia Fernandes (FCUL/Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Bachar Wehbe, Alexandre Cabral
Poster

Atmospheric optical turbulence, caused by variations in the refractive index of air due to factors like temperature, wind speed or pressure, significantly reduces the angular resolution of ground-based telescopes by causing image motion and scintillation in both daytime and nighttime observations. Differential Image Motion Monitors (DIMMs) have been widely used to quantify nighttime seeing by measuring the relative motion of stellar images formed through two sub-apertures. For daytime applications, especially solar observations, the Solar-DIMM (S-DIMM) adapts this method by measuring the differential motion of the solar limb. In this presentation, I will show the design, assembly, and the preliminary results of a S-DIMM based on a MEADE ACF-SC203/2000 8" telescope. The system incorporates a Hartmann mask with two 30 mm apertures separated by 170 mm, achieving a good b = d/D ratio of 5.6. A wedge prism is used to optically separate the two limb images on a focal plane detector and the resulting limb displacements are used to measure atmospheric seeing conditions based on the Kolmogorov turbulence model and Fried's parameter (r_0). This work was done in the scope of my master's thesis in Engineering Physics at FCUL.

Navigating through a sea of activity - a Portuguese solar telescope

André M. Silva (Instituto de Astrofísica e Ciências do Espaço (IA-CAUP))
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Poster

High-resolution spectroscopy plays a key role in the effort to detect and characterize other Earths. This objective is hindered by astrophysical signals introduced from their host stars, severely challenging the detection and characterization of exoplanets similar to Earth. An analysis of our closest star, the Sun, is presently seen as a key step to tackle this problem and has driven the development of multiple solar telescopes in recent years. To better understand and correct the signals injected by the different sources of solar activity, we need to independently evaluate their impact across a large wavelength domain. Currently, no instrument exists to take such observations! The Paranal solar ESPRESSO Telescope (PoET) aims to fill this gap. Both the hardware and software of PoET are being constructed by the Instituto de Astrofísica e Ciências do Espaço, with a first light planned for November 2025. PoET will be linked to the ESPRESSO spectrograph (ESO-VLT), allowing for simultaneous disk-resolved and disk-integrated ("sun-as-a-star") high-resolution observations of the Sun. It will deliver a novel solar dataset with spectral resolution $R > 200{,}000$, covering the full optical range (380–780 nm) in a single exposure. On behalf of the PoET team, I will present the scientific goals, the observational software and our planned observation strategies.

An Innovative High-Resolution Measurement System for Large-Scale Structures: Application to the WSS/METIS for the ESO/ELT

João Canais (FCUL/LIP)
Co-authors: João Canais (FCUL & LIP), António Amorim (FCUL & LIP), Mercedes Filho (FEUP & CENTRA), Miguel Esteves (FCUL)
Poster

This project presents a three-dimensional measurement system based on the intersection of vertical and horizontal laser curtains, designed for calibration and positioning applications with a precision below 50m. The system offers an alternative to conventional techniques such as coordinate measuring machines (CMM) and laser trackers, providing high accuracy and portability for measurements on large-scale structures. The device architecture enables the automatic acquisition of spatial coordinates by detecting the intersection point of the laser beams with specific targets, thus eliminating the need for heavy instrumentation and accessibility constraints. This measurement system will be applied on the WSS/METIS for the ESO/ELT during assembly at the Portuguese integration facility.

Calibration of a high-resolution monochromator for the calibration of a cross-dispersed echelle spectrograph

Carlos Carapeto (FCUL - Instituto de Astronomia e Ciências do Espaço)
Co-authors: Nuno M. Gonçalves, Alexandre Cabral
Poster

High-resolution (HR) spectroscopy plays a fundamental role in modern astronomy, enabling precise analysis of light from celestial sources. Cross-dispersed echelle spectrographs (CDES) are the state-of-the-art HR spectroscopy instruments widely employed in both ground and space-based observatories. These spectrographs have many applications, including the detection of exoplanets and the characterization of their atmospheres. Achieving the required level of accuracy in these applications depends heavily on reliable and stable wavelength calibration. This project focuses on the calibration and optimization of a high-resolution monochromator. The goal is to prepare it as precise wavelength-selective light source to support the calibration of CDES in intensity, contributing directly to the characterization of its efficiency. The calibration process involved studying the monochromator's slit opening and the rotation of its diffraction grating to characterize the output wavelength. This involved the usage of a low-resolution spectrograph and calibrated light sources such as laser diodes and a neon lamp to verify the wavelength accuracy and light output in the instrument. The results obtained from these procedures will be presented, as well as the characterization in efficiency throughput of a CDES. This will show the effectiveness of the calibration and the monochromator's suitability as a tool for CDES characterization.

Development of an Active Control System for Efficient Light Injection in the ANDES Spectrograph

Teresa Correia (FCUL/IA)
Poster

The European Extremely Large Telescope (ELT) will soon revolutionise ground-based observations spanning all fields of Astrophysics, from Exoplanets to Cosmology, improving, amongst others, the detection of life signatures in Earth-like exoplanets and the direct detection of the cosmic expansion re-acceleration. These advances will be made possible due to the unprecedented collection area that provides the means to achieve ground-breaking accuracy on measurements made with this telescope. One of ELT's second-phase instruments is ANDES – the ArmazoNes high Dispersion Echelle Spectrograph – an optical-infrared high-resolution spectrograph that consists of three fibre-fed cross dispersed echelle spectrographs, providing a simultaneous coverage of the spectral range from [0.4; 1.8] m at a resolution of 100,000. While still in development, the ANDES team aims to improve its efficiency. The system described in this poster is being developed at IA (Instituto de Astrofísica e Ciências do Espaço) as part of an internship in the Bachelor's in Physics Engineering program at the Faculty of Sciences of ULisboa. This is a proposed proof-of-concept as an active control system designed to guide the light injection into the fibres. The light guidance is achieved using three piezoelectric actuators mounted on a mirror that adjusts its position based on the centroid location. All of this is managed by a single interface that evaluates input from a camera, a power meter (placed at fibre's output), and the current positions of the piezo actuators.

PoET, the Paranal solar ESPRESSO Telescope: Characterization of integrating spheres to ensure frontend efficiency

Catarina Fernandes (FCUL / IA)
Co-authors: Inês Leite, Alexandre Cabral
Poster

The detection and characterization of Earth-like exoplanets around Sun-like stars is a central goal of modern astrophysics. However, in current high-resolution spectroscopic observations, stellar variability introduces significant "noise" — whose signatures distort radial velocity and transit spectroscopy measurements. To address this problem, the Paranal solar ESPRESSO Telescope (PoET) is being developed to feed both spatially resolved and disc-integrated solar light into the ESPRESSO spectrograph at ESO's Paranal Observatory. A key component in this system is the integrating sphere, which allows uniform light distribution into some frontend configurations to the science fibres that connect with ESPRESSO. Unlike other telescopes that typically use relatively large, well characterized integrating spheres (like HARPS, HARPS-N, EXPRES AND NEID), PoET presents a unique constraint that doesn't allow for their use: the collected light must travel approximately 80 meters through optical fibres to reach the spectrograph. Light transmission efficiency is critical. This study is carried out as part of an internship in the bachelor's degree in Engineering Physics at the University of Lisbon. It aims to evaluate the efficiency and spatial uniformity of smaller off the shelf integrating spheres under varying conditions — including input beam position, wavelength, and f-number — to assess its suitability for PoET's scientific needs. These spheres appear to offer higher efficiency due to a decreased internal diameter, but they are not fully characterized. The characterization and quantification of their efficiency over the target spectral waveband is critical for the PoET project.

Development of a tool for aligning cross-dispersed echelle spectrographs

Ganna Kindrak (Faculdade de Ciências da Universidade de Lisboa)
Co-authors: Nuno M. Gonçalves
Poster

The cross-dispersed echelle spectrograph (CDES) is a widely used tool in astronomy and astrophysics, especially in ground and space-based observatories that require high-resolution spectroscopy. This instrument enables the observation of high-resolution spectra, which is particularly useful for characterizing exoplanets and their atmospheres and solar phenomena, among others. Its configuration combines a primary dispersion, generated by an echelle grating operating at high diffraction orders, with a secondary dispersion, obtained through a second grating or prism (cross disperser). This combination separates the overlapping orders, forming a two-dimensional spectrum, which is recorded by an image sensor. The assembly and alignment procedure of these instruments is complex, leading to intricate setups and

tools required to optimally assemble the CDES as per the design specifications. The aim of this work was to develop a software tool to support the alignment of CDES. To this end, a graphical interface was implemented in LabVIEW. This interface uses the mathematical model of the spectrograph that is being built so that by a Monte Carlo analysis of the produced spectra it can calculate some of the design parameters. This interface integrates the spectrograph's camera controls and provides the optical assembly parameters in real time. This work allows interactive visualization of the spectrograph's alignment parameters during the alignment process, making it easier to build the spectrograph as per design specifications.

Development of a Vis/NIR Calibration Light Source for the Ariel Space Mission

Diogo Oliveira (FCUL / Instituto de Astrofísica e Ciências do Espaço)
Co-authors: Cédric Pereira, Manuel Abreu, David Alves
Poster

The Ariel Space Mission, developed by the European Space Agency, aims to study and characterise the atmosphere of about 1000 exoplanets. It will be the first mission conducting a large-scale spectroscopic survey of exoplanetary atmospheres, using observations in visible and infrared to investigate their composition, structure, and planetary evolution. A critical component of the mission is the calibration of its scientific instruments. This project focuses on the assembly and characterisation of a visible and near infrared (Vis/NIR) calibration light source – a key element of the Optical Ground Support Equipment (OGSE) – used to validate the performance of Ariel's payload. The work involves integrating different opto-mechanical components and verifying their correct operation. The stability of the light source and its flux under different configurations are characterised, along with a spectral analysis to determine the correlated colour temperature (CCT). The results of these tests are essential for validating the light source's performance and supporting the calibration campaign of the Ariel Space Mission, contributing to more precise observations of exoplanets and a deeper understanding of other planetary systems.

Onboard Metrology System for the Athena Mission

Manuel Abreu (FCUL)
Co-authors: Alexandre Cabral, Nuno Gonçalves, José Rebordão
Poster

The instrument consists of a single x-ray telescope, supported by a large area mirror focusing the photon flux alternatively onto two different instruments. The process of switching the focus between the two instruments is produced by changing the pointing of the main X-ray mirror. The verification of the alignment of the mirror optical axis with respect to each of the instruments with accuracy better than 0.5 arcsec is achieved by means of an optical Onboard Metrology System (OBM). In this work we will present final results of the calibration and testing of the OBM demonstrator developed by the Institute of Astrophysics and Space Sciences Instrumentation team.

Session 8 - The Galaxy

Gaia

Andre Moitinho (FCUL - LIP)
Focus Talk

The Gaia mission has mapped over two billion stars with unprecedented accuracy, producing results that are transforming astrophysics. This talk will provide an overview of mission's scientific goals, operations, and discoveries, as well as the major challenges of processing and calibrating its vast data volumes. Although data acquisition ended in January 2025 and the spacecraft was decommissioned in March, Gaia's most complete and accurate results are still to come. The final data releases, currently in preparation and planned for 2026 and 2030, are expected to fulfil the mission's full scientific promise and define its lasting legacy. The presentation will also highlight the nearly 20-year journey of Portuguese involvement, which began in 2006, and the ongoing work, extending through 2030, needed to deliver Gaia's full potential to the community.

Novel approaches to Galactic archaeology with machine learning

Andreas Neitzel (Instituto de Astrofísica e Ciências do Espaço)
Co-authors: T. L. Campante, D. Bossini, A. Miglio
Contributed Talk

The study of stellar populations in the Galaxy allow us to infer the interplay of different physical mechanisms that shaped its evolution and formation history to the present day. However, the chrono-chemo-kinematic properties of stellar populations are highly entangled and share significant overlap. We present a novel approach to this problem, combining manifold learning and hierarchical density-based clustering to identify stellar populations through an automated pipeline composed solely of unsupervised routines with objective optimization. After validating the method on synthetic data, we move on to its application to a chrono-chemo-kinematic catalog derived from the TESS seismic catalog, for which state-of-the-art accuracy in ages can be inferred through asteroseismology with the Bayesian inference code PARAM. The kinematics are obtained from Gaia DR3 cross-matching and the chemistry is derived from supervised learning methods trained to approximate Gaia DR3 metallicity and [/M] to APOGEE DR17-like accuracy.

Open cluster dissolution and the initial cluster mass function: modelling the age and mass distributions of clusters

Duarte Almeida (LIP, Faculdade de Ciências)
Co-authors: André Moitinho, Sandro Moreira
Contributed Talk

Most stars form in clusters that eventually disperse, integrating into the field population of their host galaxy. Thus, understanding the dissolution of stellar clusters is crucial for understanding galactic evolution. In this study, we analyse cluster dissolution in a sample of 1724 open clusters (OCs) for which we derive their limiting radii and masses using Gaia DR3 data. We developed a model that simulates the build-up and mass evolution of a population of OCs. Using the widely adopted power-law Initial Cluster Mass Function (ICMF) our model was able to reproduce the observed age distribution similarly to previous studies. However, it did not reproduce the observed mass distribution, which was not analysed in previous studies due to the unavailability of well-determined OC masses, except for a few clusters. Since the power-law ICMF was determined for embedded clusters, we investigated various ICMF functionals that could be more adequate to describe the post-gas expulsion cluster population. We found that a skew log-normal distribution provides a good match to the observations. We also determined the disruption timescale to be 2.9 +/- 0.4 Gyr, which is about twice longer than previous estimates based solely on OC age distributions. Our findings indicate that the ICMF for bound OCs differs from that of embedded clusters, implying a previously unobserved mass-dependent destruction of OCs during the emergence from their parent clouds. This, in turn, may point to a low typical star formation efficiency (less than 20%) in OCs. We also find indications of a lower limit of 60 solar masses for bound OCs in the solar neighbourhood.

Impact of Cluster Disruption on the Disc Vertical Kinematic Evolution

Sandro Moreira (FCUL-LIP)
Co-authors: Moitinho André, Almeida Duarte
Contributed Talk

Understanding galaxy evolution requires tracking their spatial and kinematic changes while modelling the underlying dynamical mechanisms. To achieve this, we need probes that enable us to resolve the time evolution of their spatio-kinematic distribution. Open clusters (OCs) span a wide range of ages, from a few Myr to several Gyr, providing the possibility to follow the evolution of their spatio-kinematic properties and, in turn, the evolution of the Milky Way throughout a large part of its history. The old OC population exhibits a larger scale height and hotter kinematics than its younger counterparts. These differences are traditionally attributed to disc heating mechanisms similar to those affecting field stars or to a historically thicker disc. In recent work, we showed that the increase in OC scale height (SH) with age can be largely explained by the gradual disruption of clusters near the Galactic plane due to disc-related phenomena, such as encounters with giant molecular clouds. We developed a computational model that forms OCs, follows their orbits, and subjects them to various disruption mechanisms. This model successfully reproduces both the observed SH evolution and the total number of surviving clusters as a function of age. Building on this spatial analysis, we now examine the kinematic perspective. We show that our model, using the same disruption mechanisms, naturally reproduces the observed increase in vertical velocity dispersion of the OC population with age. The progressive disruption of lower-altitude clusters not only reshapes the spatial distribution but also influences the velocity distribution, revealing the link between cluster disruption and vertical kinematic evolution

Extinguishing starlight from absorption lines

Rita Santos (CENTRA - Instituto Superior Técnico)
Co-authors: Santiago González-Gaitán, Joseph Anderson, Ana Mourão
Contributed Talk

We present a study of interstellar absorption features in galaxies observed with integral field spectroscopy (IFS) using the ESO-MUSE instrument. The use of IFS allows us to extract measurements of key absorption lines,ÄîNa,ÄØI D, Ca,ÄØII H&K, K,ÄØI ,Äîto probe the Milky Way (MW) interstellar medium (ISM). Equivalent widths (EWs) are measured using non-parametric integration on observed spectra. These measurements are compared with the values predicted from empirical relations between E(B,ÄìV) and absorption line strength (Poznanski, 2012), using 2D dust extinction maps, such as those recalibrated by Schlafly & Finkbeiner (2011). We employ Voronoi binning in order to improve the signal-to-noise of our EW measurements while preserving spatial structure. This methodology is currently being validated on a pilot galaxy (NGC 3244) and will enable systematic mapping of ISM features across the AMUSING galaxy sample.

Improving Young Cluster Ages Using Gaia DR3 Synthetic Photometry

Pedro Azoia (LIP - Faculdade de Ciências)
Co-authors: André Moitinho, Sandro Moreira, Duarte Almeida
Poster

The ESA Gaia mission has enabled the characterisation of open clusters (OCs) on an unprecedented scale. As a result, the literature now contains several catalogues providing cluster reddening, distance, and age estimates, along with other parameters, for hundreds to thousands of objects. While distances can be directly obtained from parallaxes, reddening and ages in these catalogues are derived simultaneously through isochrone fitting to Gaia G, BP, and RP photometry using a variety of techniques, such as Bayesian inference and different neural network architectures. However, the Gaia G, BP and RP filters are very broad, and lack specific filters for probing both sides of the Balmer jump, reducing sensitivity to fine extinction variations and making it difficult to disentangle reddening effects from those of stellar temperature. This limitation may introduce systematic uncertainties in cluster age estimates, particularly for young OCs. A possible solution is to cross-match with other surveys that include more suitable passbands. However, current wide-area imaging surveys with the necessary wavelength coverage are ground-based, leading to a loss of the exquisite photometric precision provided by Gaia"s space-based flux measurements. In this project, we address this issue using the Gaia Synthetic Photometry Catalogue (GSPC) from DR3. We focus on the UBVRI bands, which are well-suited for reddening determinations in young clusters and provide a rich dataset for comparison with published OC parameter studies. Our analysis of four Gaia-based OC catalogues reveals a systematic overestimation of E(B-V), leading to inflated age estimates for clusters younger than 100 Myr.

Testing peculiar abundances in Globular Clusters

Ricardo Vaca (Universidade do Porto)
Co-authors: Ivan Cabrera-Ziri, Gladis Magris
Poster

Historically, globular clusters (GCs) have been thought of as simple stellar populations and, due to their old age and low metallicity, are excellent tracers of the evolution of their parent galaxy. However, studies have shown that the stars belonging to individual clusters can be divided into different populations with different chemical abundances while maintaining a very small age difference. Through these observations, studies have found that individual stars of almost all GCs show variations in the abundances of certain elements, such as He, Na, O, N, C, Al, and sometimes Mg . These variations are present even in main sequence stars, suggesting that they are present during the formation of the star rather than being a product of stellar evolution. Despite decades of effort, no satisfactory explanation has yet been found to describe the mechanism responsible for the observed chemical patterns. Finding the origin of these variations remains a major challenge in stellar and galactic astrophysics, and the origin of this phenomenon is still an open question. We tested the three most popular models proposed for the origin of this phenomenon: asymptotic giant branch stars (AGBs), high-mass interacting binaries (IBs), and fast rotating massive stars (FRMSs) in twenty-six clusters (increasing the number of clusters in previous studies by more than a factor of three) to see if any of them can replicate the observations. We also included the study of the abundances of N, C, Mg, and Al, extending previous studies that mainly focused on the abundances of He, O, and Na. In addition, we constructed an empirical model to test whether one could explain the chemical signatures of the "enriched" population of GC stars with a fixed source and dilution process based on empirical data.

Session 9 - Large Scale Structure & Cosmology

Tensions, hints, and unexpected cosmologies

Andrew Liddle (IA-Lisbon)
Overview Talk

Despite the considerable successes of the standard LambdaCDM cosmology, the topic has recently been plagued by marginally-significant signs of deviations from this paradigm. Notable amongst these are the 5-sigma Hubble tension and the 3 to 4-sigma hints of evolving dark energy density identified by the DESI collaboration. I review both the LambdaCDM successes and these discrepancies, focussing in particular on the unexpected nature of the cosmologies that they point towards and on what this means for secure cosmological inference. [Based on work carried out in collaboration with Marina Cortês.]

Euclid

Ismael Tereno (IA-Lisbon)
Focus Talk

The ESA Euclid mission, in operation since 2023, is designed to probe the dark universe via weak gravitational lensing and galaxy clustering. In addition, the combination of wide field-of-view and high-resolution optical imaging enables a wide range of science as evidenced by the analyses of 30 million objects in the 0.45% of the final survey area recently released on March 2025. In this talk, I will give an overview of the mission, its science goals and achievements, and operational challenges. I will also highlight Portuguese contributions, including the leadership of the Instituto de Astrofísica e Ciências do Espaço in Euclid's mission planning.

HI Intensity mapping with the MeerKAT

José Fonseca (IA - U.Porto)
Co-authors: Mário G. Santos & the MeerKLASS Collaboration
Contributed Talk

The future Square Kilometre Array Observatory (SKAO) will perform an HI intensity mapping (IM) survey over 20,000 sqdeg from $z = 0.35 - 3$. With its precursor, the MeerKAT, an international science team, the MeerKAT Large Area Synoptic Survey (MeerKLASS), has an ongoing HI IM survey. In this communication I will review the MeerKAT specifications and its potential for cosmology. I will summarize all we have done to perform HI IM in practice, including calibrating data, modeling instrumental settings, systematic errors, and terrestrial, galactic and extra-galactic contamination. We will finish presenting the tentative measurement of the cross-power spectrum and our prospects for future science with MeerKLASS.

Dark Gravity: Beyond Einstein's General Relativity

Francisco Lobo (Institute of Astrophysics and Space Sciences, University of Lisbon)
Contributed Talk

Modern astrophysical and cosmological models are faced with two severe theoretical difficulties, that can be summarized as the dark energy and the dark matter problems. Relative to the former, it has been stated that cosmology has entered a 'golden age', in which high-precision observational data have confirmed with startling evidence that the Universe is undergoing a phase of accelerated expansion. Several candidates, responsible for this expansion, have been proposed in the literature, in particular, dark energy models and modified gravity, amongst others. One is liable to ask: What is the so-called 'dark energy' that is driving the acceleration of the universe? Is it a vacuum energy or a dynamical field ("quintessence")? Or is the acceleration due to infra-red modifications of Einstein's theory of General Relativity? In the context of dark matter, two observations, namely, the behavior of the galactic rotation curves and the mass discrepancy in galactic clusters, suggest the existence of a (non or weakly interacting) form of dark matter at galactic and extra-galactic scales. It has also been proposed that modified gravity can explain the galactic dynamics without the need of introducing dark matter. We briefly review some of the modified theories of gravity that address these two intriguing and exciting problems facing modern physics.

Examining the Hubble tension with differences in supernova and host galaxies properties

Gonçalo Martins (CENTRA - Instituto Superior Técnico)
Co-authors: Ana M. Mourão, João Duarte and Santiago González-Gaitán
Contributed Talk

The Hubble constant H0 gives us the Universe's expansion rate at present-time and shows a persistent 4–6 σ discrepancy between early- and late-time measurements. This discrepancy, known as the Hubble tension, may stem from systematics in the late-time measurement of the Cepheid-based distance ladder: differences in the properties of Type Ia supernovae (SNe Ia) and their host galaxies between the calibration sample (with Cepheids and SNe) and the Hubble Flow (HF) sample (more distant galaxies hosting only SNe). In this project, we test how closely matching the distributions of some properties such as the SNe colours (c), stretch (x_1), host stellar mass (M), and specific star formation rate (sSFR) between these samples can affect the H0 estimation. We generate HF subsamples whose properties better match the calibration sample and use them to derive a more accurate correction for SNe Ia luminosities. Our results suggest that calibration hosts may not fully represent HF galaxies in mass and sSFR, and that while a HF subsample alone may not resolve the tension, certain SNe populations appear consistent with lower H0 values.

Structure Formation From Cosmic Domain Wall Collapses

Clara Winckler (Instituto de Astrofísica e Ciências do Espaço (IA)/ Universidade do Porto)
Co-authors: Pedro Avelino, Lara Sousa
Contributed Talk

A series of symmetry-breaking phase transitions in the early universe is expected to have caused the formation of networks of sheet-like topological defects called domain walls whose collapse could leave observable imprints in current-day massive non-linear structures. We use the parameter-free version of the velocity-dependent one-scale model to provide an estimate of their decay energy, which is expected to act as a seed for density perturbations of the background matter field. We calculate the current mass of the resulting non-linear objects depending on collapse redshift and wall tension, and thus show that domain walls can be responsible for the formation of objects with masses up to those of current-day galaxy clusters. Based on this, we estimate the maximal fraction of such objects and confirm that the contribution of standard domain walls to structure formation is always subdominant. Networks of walls based on a biased scalar field potential, however, are subject to much less stringent observational constraints, allowing for a significantly larger collapse energy. Based on our analysis, we are able to show that the collapse of such biased wall networks can provide a significant contribution to structure formation, and, in particular, a mass excess at high redshifts of $7 \leq z \leq 9$ recently suggested by JWST data.

Analytical Methods for Realistic Cosmic Strings and Superstrings

Pedro Belo Barbosa (University of Porto)
Co-authors: Prof. Carlos Martins
Poster

Cosmic strings are one-dimensional topological defects formed in the early Universe during symmetry-breaking phase transitions. Despite their microscopic width, their length can span cosmological scales, forming networks that evolve dynamically. As these strings move through spacetime, they may self-interact and generate loops, which subsequently decay, contributing to the loss of energy from the network. While various mechanisms responsible for this energy dissipation are well studied, this work focuses on scenarios where strings may instead gain energy. Specifically, I investigate current-carrying cosmic strings within the framework of CVOS model, extended to include the influence of an external magnetic field. This modification alters the string dynamics, leading to a richer spectrum of solutions, including both energy-gaining and energy-losing configurations. Additionally, I explore the parameter space of the model to identify possible scaling solutions and characterize the conditions under which they emerge.

Probing Unification Scenarios with Big Bang Nucleosynthesis

Luna Dreyer (Phy in the Sky, Centro de Astrofísica da Universidade do Porto)
Co-authors: Carlos Martins, David Hilditch
Poster

Big Bang Nucleosynthesis (BBN) is an observational cornerstone of the Hot Big Bang model and a sensitive probe of physics beyond it. Although some analytic approximations can be made, a fully consistent analysis must be done numerically, starting with the classic code by Kawano [Kawano 1992; Kawano, Malaney and Smith 1993] and leading to the recently developed PRyMordial[Burns, Tait and Valli 2024], a publicly available Python code. An example of physics beyond the standard model to which BBN is sensitive are Grand Unified Theory (GUT) models. A self-consistent perturbative analysis of the effects of variations in nature's fundamental constants, which are unavoidable in a broad class of GUT models, has recently been developed[Coc et al. 2007; Martins 2021]. The specific goal of this project is to implement this perturbative approach in the PRyMordial code. This will enable a subsequent use of the extended code to obtain constraints on GUT models using current observations, and also detailed forecasts of improvements expected with next generation astrophysical facilities, such as the ANDES spectrograph for the ELT[Martins et al 2024].

Challenging the Cosmological Principle: Angular Homogeneity Scale in the Era of Large Galaxy Surveys

Pedro Fanha (University of Porto)
Co-authors: P. Fanha, A. Da Silva, J. Fonseca, J.P. Mimoso
Poster

How uniform is the Universe across cosmic distances? Underlying the standard CDM cosmological model, the cosmological principle assumes large-scale homogeneity. Quantifying cosmic structure through angular (sky-projected) clustering and fractal geometry provides a powerful lens to investigate when, and how, the Universe transitions to homogeneity, and modern galaxy surveys allow us to test this foundational idea with increasing precision. In this work, we assess the robustness of different angular fractal dimension estimators and their associated uncertainties in determining both the fractal dimension profile and the angular homogeneity scale, _H. Using state-of-the-art numerical galaxy survey simulations, we implemented and tested a suite of methodologies based on the Landy–Szalay (LS) estimator. These include both parametric models and non-parametric approaches powered by Symbolic Regression — a machine learning technique that can uncover analytical expressions directly from data. Our results highlight the strengths and limitations of various estimators and show that symbolic regression, in particular, can effectively capture key trends in the fractal dimension evolution and _H determination — often with improved interpretability and flexibility. We also introduce new ways of estimating _H that are less sensitive to sample variance and, importantly, are cosmological model-independent. These findings provide valuable tools for future cosmological analyses and offer a robust framework for testing the transition to homogeneity in upcoming galaxy surveys such as LSST, Euclid, and DESI.

Comparing Dark Energy Models in Modified Theories of Gravity

Paulo Monteiro (Center for Astrophysics, University of Porto)
Poster

The wide range of modified gravity theories proposed to address the limitations of General Relativity (GR) presents a challenge in distinguishing between them. In particular, the Geometric Trinity of Gravity - comprising GR (based on spacetime curvature), Teleparallel Gravity (based on torsion), and Symmetric Teleparallel Gravity (based on nonmetricity)- are dynamically equivalent. This raises fundamental questions about the underdetermination of the geometric nature of spacetime and whether observational distinctions between these frameworks are possible. To explore deviations from GR, we study nonlinear extensions of these theories: f(R), f(T) and f(Q) as well as extensions involving boundary terms: f(T,B) and f(Q,B). Using a reconstruction approach, we compare these theories by evaluating which of them are compatible with a CDM background expansion history. Our main objective is to determine which of these theories can account for cosmic acceleration without invoking a cosmological constant. We show that for f(R), f(T) and f(Q) theories, an exact CDM behavior can only be reproduced by the linear limit with a cosmological constant, but for f(T,B) and f(Q,B) there is an infinite number of such theories. We also discuss the validity of these theories at local scales.

Modified Gravity from the viewpoint of Backreaction

Bruno Parracho (IA - UPORTO)
Co-authors: Work carried out with my supervisors, José Pedro Mimoso and Pedro Avelino
Poster

As observational cosmology advances, models in cosmology will have to take into account effects previously neglected, such as backreaction, which appears due to inhomogeneities at large scales. One phenomenon cosmologists seek to explain is the late-time cosmic acceleration via backreaction, however many disagree on the magnitude of the effect on cosmic acceleration. We will study how backreaction appears in scalar-tensor theories by implementing a gauge-invariant geodesic light-cone averaging formalism. One interesting part of scalar-tensor theories is that in the Einstein frame, a particular choice of scaling, the theory becomes much like the LCDM model. Therefore a natural analysis is to examine how the backreaction in the Einstein frame behaves. As well as explore how the averaging procedure works in the Einstein frame.

Connecting General Relativity with Scalar tensor theory à la Buchdahl

David Pereira (Instituto de Astrofísica e Ciências do Espaço; Faculdade de Ciências da Universidade de Lisboa)
Co-authors: José Pedro Mimoso, Francisco S.N Lobo
Poster

Since the development of Brans–Dicke gravity (BD), it has become well-known that a conformal transformation of the metric can reformulate this theory, transferring the coupling of the scalar field from the Ricci scalar to the matter sector. Specifically, in this new frame, known as the Einstein frame, Brans–Dicke gravity is reformulated as General Relativity (GR) supplemented by an additional scalar field, a minimal extension of GR that is fundamental to cosmology and high-energy theories. In 1959, Hans Adolf Buchdahl utilized an elegant technique to derive a set of solutions for the vacuum field equations within this gravitational framework. In this presentation, we revisit Buchdahl's original approach and extend it to incorporate the effects of a cosmological constant, leading to new solutions within a version of Brans–Dicke theory that includes a quadratic scalar potential. In addition, we explore the massless scalar field case in Brans–Dicke theory using these techniques. Extensions of Buchdahl's method to higher-dimensional spacetimes and to scenarios involving multiple scalar fields will also be discussed.

Session 10 - Education and Communication

'Exoplanets in bytes' - a hackathon for secondary students to train AI models for the ESA's ARIEL Space Mission

Cátia Cardoso (Ciência Viva)
Co-authors: Pedro Mota Machado, IA / FCUL Marília Simões, ML Analytics Luís Simões, ML Analytics Adelina Machado, Ciência Viva / ESERO Portugal Miguel Esperança, Ciência Viva / ESERO Portugal Fátima Pinto, Ciência Viva / ESERO Portugal
Contributed Talk

Exoplanets and Artificial Intelligence was the focus of the educational hackathon organized at the Pavilion of Knowledge, in Lisbon. Approximately, 50 secondary school students from all over the country accepted the challenge to explore exoplanets data, using artificial intelligence (AI) models. This was a unique opportunity for the students to use AI in the context of a space mission. Participants used simulated data to refine an AI model developed by ML Analytics for the ESA's ARIEL Space Mission. This initiative is an intersection of an educational project with a real scientific outcome. This event developed students" problem-solving skills and contributed to the advancement of professional AI models for the ARIEL Space Mission. The results of the hackathon were presented during the Ariel Space Mission Consortium Meeting, in Lisbon, in 2024. The hackathon was organized by ESERO Portugal, a partnership between Ciência Viva and the European Space Agency, with the collaboration of the Institute of Astrophysics and Space Sciences, the Faculty of Sciences of the University of Lisbon and ML Analytics.

O ensino da astronomia na escolaridade obrigatória, um roteiro para o futuro, baseado no diagnóstico do presente

Ilídio André Costa (Agrupamento de Escolas de Santa Bárbara / Planetário do Porto - Centro Ciência Viva / Instituto de Astrofísica e Ciências do Espaço - Universidade do Porto)
Co-authors: Mario João Monteiro Filipe Pires
Contributed Talk

Em 2015, com a instalação de um novo sistema de projeção digital, o Planetário do Porto ‚Äì Centro Ciência Viva (PP-CCV), iniciou um processo exaustivo de reformulação de todo o seu Programa Educativo. A ele passou a associar, no ano seguinte, um Plano de Formação contínua docente e, em 2018 uma componente investigativa sobre a sua atividade. Numa fase inicial, a investigação recaiu sobre as práticas de comunicação de ciência dos astrónomos, do Centro de Astrofísica da Universidade do Porto (CAUP) e sobre a avaliação dos novos Programas Educativo (implementado com mais de 50000 visitantes anuais) e de Formação contínua (1332 professores, de todo o território nacional e países da CPLP, selecionados a partir de 3208 inscritos). Seguiu-se a implementação e análise de um projeto de ciência cidadã (que integrou professores do 1 ciclo em equipas de investigação do Instituto de Astrofísica e

Ciências do Espaço, IA) e a análise do conhecimento dos professores sobre conceitos chave de astronomia (e suas atitudes e crenças face a esta ciência). Mais recentemente, a equipa debruçou-se sobre a análise dos documentos curriculares, para determinar a relevância da astronomia na escolaridade obrigatória e a forma de fazer chegar, ciência contemporânea (resultados e processos científicos atualizados), a públicos tipicamente afastados do envolvimento com esta ciência. Para este último desiderato, a equipa mapeou as zonas de Portugal continental, com menor envolvimento espontâneo com a ciência para, então, criar e implementar um modelo de intervenção nessas zonas. De uma forma genérica, e para o roteiro sobre o ensino da astronomia que se pretende neste trabalho apresentar, todo esse trabalho revela que: i) Nos últimos anos, com a entrada em vigor dos novos documentos curriculares, astronomia tem vindo a desaparecer gradualmente da escolaridade obrigatória ‚Äì os conteúdos de astronomia ainda existentes (alguns dos quais considerados pelos astrónomos como menos relevantes) surgem apenas em alguns anos de escolaridade, num número reduzido de disciplinas escolares e com uma abordagem esporádica e superficial. ii) Existem muitíssimas oportunidades, no currículo nacional, para utilizar a astronomia como ciência portal para o ensino das outras ciências (matemática, geografia, física, química, biologia, geologia) e, mesmo, das disciplinas associadas às Humanidades, Línguas e Artes. Tal, potenciado pelo facto da astronomia ser a ciência que mais motiva os alunos para a aprendizagem. iii) A maioria dos professores em formação contínua, não tem, à partida, um gosto particular pela astronomia. Na verdade, a maioria nunca, na sua formação inicial ou continua, havia contactado com a astronomia. Com pouco gosto e pouca astronomia para lecionar não investem em formação continua nessa área. Sendo assim, evitam, mesmo, lecionar os (poucos) conteúdos curriculares de astronomia. iv) A principal motivação para as visitas escolares ao PP-CCV são os conteúdos curriculares associados à astronomia. Na verdade, o número de visitantes escolares aumenta quando a astronomia se torna mais relevante no currículo, e diminui quando o contrário acontece. v) Os professores têm níveis de conhecimento substantivo sobre a astronomia, muito baixos (M=20,6%; DP=9,5%), relacionáveis diretamente com lacunas na formação inicial e, pelo que acima de diz, com a falta de relevância da astronomia no currículo nacional. vi) Os professores têm ao seu dispor muitíssimos recursos educativos e de alta qualidade, mas anseiam por alternativas baseadas em ciência contemporânea e ligadas, intimamente, aos conteúdos que têm de lecionar. vii) Os professores apresentam crenças epistemológicas, muito desfasadas do que é, hoje, a astronomia e a forma como esta se constrói. viii) A falta de envolvimento espontâneo com a astronomia, nas regiões mapeadas no nosso trabalho, fica a dever-se, essencialmente, a falhas na democratização da ciência e não de uma opção consciente das populações. O que aqui se apresenta tende a revelar que aos extraordinários resultados da assunção da astronomia como ciência portal para o ensino de outras áreas do saber, parece adicionar-se um processo de facilitação do seu desaparecimento curricular. As consequências para o ensino da astronomia são claras, mas este status quo também tem um forte impacto na divulgação da astronomia, pelos centros de ciência e, no fim da cadeia, na própria investigação em astronomia (uma vez que a opção de seguir uma carreira de investigação em astronomia se torna menos provável). Urge, pois, associar às oportunidades interdisciplinares que a astronomia cria, a manutenção, nas disciplinas escolares já existentes, da sua identidade curricular. Esta manutenção será essencial para a mais elementar literacia científica quotidiana e que permitirá usufruir das oportunidades da participação portuguesa nas missões do Observatório Europeu do Sul (ESO) e na Agência

Espacial Europeia (ESA). É, assim, objetivo último do presente trabalho, apresentar um roteiro que enfrente a situação atual e que, no seio da Sociedade Portuguesa de Astronomia (SPA), adicione à sua reconhecida relevância científica, uma renovada relevância nos destinos da escolaridade obrigatória em Portugal.

What do people really talk about in planetarium sessions? A study of the topics communicated.

Joana Marques (Instituto de Astrofísica e Ciências do Espaço, Universidade de Coimbra)
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Contributed Talk

Planetariums are key settings for science education and communication. They allow for the exploration of a wide range of astronomy topics and ideas. Usually, sessions are adapted and tailored to their public, and content plans are prepared and put in practice. But, at the end, what is exactly communicated during these sessions? What do guides and their audiences really talk about? To answer these questions, we video and audio recorded planetarium sessions, with minimum disturbance, in different Portuguese institutions. The content communicated in these live sessions was then analysed. In this talk we present preliminary results of the characterization of that content and explore its connections with the Portuguese curriculum guidelines, and the IAU guidelines for astronomy literacy.

PLOAD – 10 anos de Astronomia para o Desenvolvimento em Português

Joana Marques (Instituto de Astrofísica e Ciências do Espaço, Universidade de Coimbra)
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Contributed Talk

O Grupo Lusófono de Astronomia para o Desenvolvimento (PLOAD, na sigla em inglês) é uma iniciativa do Office of Astronomy for Development (OAD) da União Astronómica Internacional (IAU), dedicada a promover o uso da astronomia como ferramenta para o desenvolvimento sustentável em países e comunidades de língua portuguesa. Coerente com o plano estratégico da IAU, o PLOAD disponibiliza acesso a recursos de qualidade, estabelece parcerias com a comunidade, em particular com instituições educacionais, em harmonia com a diversidade cultural da observação do céu na língua e história destas comunidades. Ao longo da sua primeira década de existência, o PLOAD consolidou uma rede diversa e colaborativa, que tem proporcionado oportunidades únicas de desenvolvimento científico, tecnológico, educacional, e social. As actividades desenvolvidas incluem a criação de recursos educativos acessíveis, realização de formações e eventos, apoio a projectos locais, e promoção da inclusão através da ciência. Nesta apresentação, iremos refletir sobre as principais acções globais e locais realizadas nos últimos anos, destacando os impactos alcançados e os desafios enfrentados. Apresentaremos ainda a iniciativa comemorativa dos 10 anos do PLOAD – uma chamada de Arte Postal – que convida pessoas de todas as idades a refletirem sobre o papel da astronomia no desenvolvimento, através da expressão artística.

Students as Analog Explorers

Rosa Doran (NUCLIO)
Co-authors: Gustavo Rojas, Carlos Santos, Leonel Godinho
Contributed Talk

The project EXPLORE, co-funded by the Erasmus Project, has as a main objective the active involvement of school students in activities that simulate the Moon or Mars Environments. Participants are invited to participate in a simulation of a mission in a hostile environment, mimicking the expected settings of a real analog mission. All students from the participating schools are invited to actively participate in the project by being involved in a series of activities where they are introduced to the experiments foreseen for the future mission. STEAM-related content is delivered to the students through a student-centred approach and using innovative means to support the development of their competencies and to assess their progress. Two analog missions are foreseen within the framework of the project. They are taking place in the analog facilities being created in the Observatory Largo do Alqueva in Monsaraz, Portugal. In this talk, we will present the results of the first mission and the preparations for the future ones.

Astro-Journeys: Co-Creation of Astronomy Learning Experiences Across Europe

Sara Anjos (NUCLIO, Universidade do Minho)
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Contributed Talk

Astro-Journeys is a transnational Erasmus+ initiative (2024-2027) that seeks to enhance the teaching of astronomy through the co-creation of personalised learning paths, guided by artificial intelligence (AI) and based on the “Big Ideas in Astronomy” framework. Co-ordinated by CY Cergy Paris Université, the project brings together a consortium of academic and outreach institutions from France, Germany, Portugal, Spain and Greece. This communication presents the pedagogical design, implementation strategies and preliminary knowledge of the project’s initial development phase. Astro-Journeys supports teachers and students - mainly at primary and secondary level - in designing interdisciplinary, research-based learning journeys that align with national curricula while promoting scientific reasoning, inclusivity and creativity. A central component of the platform is the integration of AI-assisted tools that facilitate educational content, suggest relevant astronomical resources and adapt to diverse learning needs. Professional development modules for educators are provided through

blended formats, promoting sustained engagement and collaborative curricular innovation. The presentation will further explore how the project contributes to science communication by fostering partnerships between formal education, research institutions, and science centers, thus bridging gaps between scientific knowledge and public understanding. Emphasis will be placed on the project"s potential to serve as a scalable model for participatory, technology-enhanced science education across Europe.