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Preface

The Reunión Regional Latinoamericana de Astronomía / Latin American Regional IAU Meeting (LARIM) started in 1978 and has cycled through Latin America from Santiago (1978), to Mérida (Venezuela, 1981), Buenos Aires (1983), Rio de Janeiro (1984), Mérida (México, 1986), Gramado (1989), Viña del Mar (1992), Montevideo (1995), Tonantzintla (1998), Córdoba (2001), Pucón (2005), Isla Margarita (2007), Morelia (2010), Florianópolis (2013), Cartagena de Indias (2016), Antofagasta (2019) and, for the second time, back to Montevideo for its XVII edition in 2023.

The XVII LARIM was held from November 27 to December 1, 2023, at the Centro de Conferencias de la Intendencia, in the heart of Montevideo. Originally scheduled for 2022, the meeting was rescheduled for 2023 because of the COVID-19 pandemic. Organizing the first LARIM after the pandemic presented significant challenges and uncertainty. However, despite these difficulties, ensuring the continuity of LARIM was essential, as it remains a key forum for fostering the development of regional astronomy. The event ultimately provided a much-needed opportunity for astronomers from Latin America and beyond to reunite in person, discuss ongoing projects and results, and strengthen collaborations that will shape the future of astronomy in the region.

The meeting featured plenary sessions, parallel sessions, and two poster exhibitions. The program was arranged according to the nine IAU Divisions, spanning a wide range of topics, including but not limited to planetary systems, astrobiology, the Sun, stars and stellar physics, stellar systems, star formation, interstellar medium, local universe, galaxies, AGN, cosmology, compact objects, high-energy astrophysics, instrumentation, facilities, technologies, astroinformatics and big data, fundamental astronomy, history, education, outreach, heritage, and astronomy for development.

In the plenary sessions, invited speakers provided comprehensive accounts of the state-of-the-art in observational and theoretical astronomy, along with insights into astronomical facilities and data management. There were 28 parallel sessions throughout the week, grouped into three simultaneous sessions, with at least one session per division. The event hosted 391 participants and featured 20 invited plenary talks, 140 contributed talks, and 232 posters. The Scientific Organizing Committee (SOC) made efforts to ensure diverse participation, in terms of gender balance and early career scientist representation in the field. All the sessions were publicly broadcast live via streaming. As part of the parallel activities of the XVII LARIM, several outreach and educational initiatives were organized in Montevideo. Five public talks were given during the week by prominent astronomers from Chile, Argentina and the United States. The III Workshop on Astronomy Beyond the Common Senses for Accessibility and Inclusion was held at the Montevideo Planetarium from 29 to 30th November, in parallel with the LARIM. The I Workshop of Astronomy in the Classroom for high-school teachers was held after the meeting on December 14th at the Instituto de Perfeccionamiento y Estudios Superiores.

The SOC aimed to have a well-balanced representation of colleagues from various Latin American countries, who were appointed by national astronomical societies. The SOC members were: Gonzalo Tancredi (Uruguay, Chair), Cecilia Mateu (Uruguay, co-Chair), Andrea Costa (Argentina), Melina Bersten (Argentina), Reinaldo Ramos de Carvalho (Brazil), Lucimara Martins (Brazil), Julio Carballo (Chile), Verónica Motta (Chile), Camilo Delgado (Colombia), Miguel Chavez (México), Vladimir Ávila-Reese (México) and Gladis Magris (Venezuela). The Local Organizing Committee (LOC) was predominantly composed of researchers and postgraduate students in Astronomy from the Universidad de la República, along with representatives from the Planetario de Montevideo and Observatorio Astronómico Los Molinos (DICYT, Ministerio de Educación y Cultura), which are key entities in astronomy outreach in Uruguay. The LOC members were: Juan José Downes (UdelaR, Chair), Rafael Bertolotto (UdelaR), Sebastián Bruzzone (UdelaR, CURE), Mauro Cabrera (UdelaR), Manuel Caldas (UdelaR), Bruno Domínguez (UdelaR), Tabaré Gallardo (UdelaR), Álvaro Guaimare (UdelaR), Andrea Maciel (OALM), Silvia Martino (UdelaR), Cecilia Mateu (UdelaR), Oscar Méndez (Planetario de Montevideo), Nicolás Pan (UdelaR), Santiago Roland (UdelaR, CURE) and Gonzalo Tancredi (UdelaR).

The XVII LARIM was generously supported by the following sponsors: Intendencia de Montevideo, Comisión Sectorial de Investigación Científica de la Universidad de la República; Programa de Desarrollo de las Ciencias Básicas and Instituto de Astronomía de la Universidad Nacional Autónoma de México. It also received support and collaboration from the following institutional organizers: International Astronomical Union, Facultad de Ciencias de la Universidad de la República, Sociedad Uruguaya de Astronomía, Planetario de Montevideo, Centro Universitario Regional del Este de la Universidad de la República and Observatorio Astronómico Los Molinos. The publishing of these proceedings is possible thanks to the Revista Mexicana de Astronomía and Instituto de Astronomía de la Universidad Nacional Autónoma de México. The success of the XVII LARIM would not have been possible without the contributions and support of numerous individuals for the meeting's scientific content and logistics. We extend our gratitude to:

- The manager and personnel of Easy Planners, in particular the Director Pablo Ferrari.
- Participants, speakers and chairs for their valuable participation and contributions.
- Members of the SOC and LOC for their dedication and efforts in organizing the meeting.
- Mauro Cabrera, Rafael Bertoloto, Bruno Dominguez and Nicolás Pan from the LOC for outstanding management of the transmission and talk assistance during all the sessions.
- All volunteers and students who provided assistance during the conference particularly Valeria Abraham, Lucas Barrios, Rodrigo Cabral, Matias Hernández, Pablo Lemos, Diego Martirena and Lucia Velasco.
- Alejandro Galli from Sociedad Uruguaya de Astronomía and Daniel Musetti from Intendencia de Montevideo for valuable support in key aspects of the organization.
- Hugo Fatoruzzo & Quinteto Barrio Sur for an outstanding musical performance and commitment to the organization.
- Florencia Barragan, Roque Villamil and Ramón Cubilla for artistic design and assistance during the painting of the Montevideo sign, and many other conference's participants.

Their generous support contributed to making the XVII LARIM a fruitful and joyous event.

The final report submitted to the IAU Executive Committee is available on the IAU website: `https://www.iau.org/static/scientific_meetings/larim/final-report-LARIM-XVII.pdf`

Gonzalo Tancredi, Cecilia Mateu & Juan José Downes
XVII LARIM Proceedings Editors

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A six dimensional view of stellar and planetary systems with high precision astrometry

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Keywords: *astrometry, ISM: clouds, planets and satellites: general, stars: distances, stars: fundamental parameters, stars: protostars*

Abstract

High-precision astrometry provides the six-dimensional information (position and velocity) of individual members in stellar systems. In this contribution, I present our work on using radio astrometry, complemented with *Gaia*, to study the 3D structure of star-forming regions and the internal kinematics of young stellar clusters. I also present recent wok on astrometric searches for exoplanets in single and binary stars and the characterization of their 3D orbits.

Resumen

Astrometría de alta precisión proporciona información sobre la posición y velocidad de miembros individuales en sistemas estelares. En esta contribución, presento nuestro trabajo sobre el uso de la radio astrometría, complementada con *Gaia*, para estudiar la estructura 3D de regiones de formación estelar y la cinemática interna de cúmulos estelares jóvenes. También presento trabajos recientes sobre búsquedas astrométricas de exoplanetas en estrellas aisladas y binarias, así como la caracterización 3D de sus órbitas.

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1. Introduction

Significant progress in astrometric accuracy was achieved in the last decade with the launch of the *Gaia* mission and the development of Radio Interferometry. In the field of star and planet formation, the unprecedented astrometric precision provided by these instruments opened new lines of research that were previously inaccessible. *Gaia* is collecting the parallax and proper motions of > 1000 million stars, which represents ∼1% of the stars in the Galaxy. In the current Data Release 3 (DR3), uncertainties in parallax and proper motions are 10–20 μas and 10–20 μas yr^{-1}, respectively, both for a magnitude below $G = 15$ (Gaia Collaboration et al., 2023). For astrometric studies in star-forming regions, however, it is necessary to complement *Gaia* measurements with the astrometry provided by radio interferometers. This is because star formation occurs in molecular clouds, within dense cores rich in dust. Radio observations, on the other hand, can overcome the high dust extinction, allowing astrometric measurements of the youngest and most embedded objects.

2. 6D structure of molecular clouds and young stellar systems

We conducted the Gould's Belt Distances Survey (GOBELINS), a radio astrometric survey of (embedded) young stellar objects located in the most prominent and nearby star-forming regions (Taurus, Perseus, Serpens, Ophiuhcus and Orion). GOBELINS used the Very Long Baseline Array (VLBA) to observe the non-thermal radio continuum emission from ∼ 270 targets, delivering high precision astrometric parameters of about 100 stars. Published catalogs contain parallaxes and distances with an accuracy of 0.3% to a few percent, and proper motions accuracies better than 0.2 mas yr^{-1}. We also obtained the spatial velocities of a subset of the stars, as well as stellar masses from monitoring of binary systems.

Combining *Gaia* DR1 and radio astrometry, we found that distances and velocities of individual clouds in the Taurus complex change significantly across the cloud (Galli et al., 2018). The measurements revealed the depth of the cloud along the line of sight to be 36 pc. Later, we extended the sample of young stars with six-dimensional information

by using *Gaia* DR2 astrometry and radial velocities from the literature (Galli et al., 2019). We found relative distances among the various clouds of 25 pc on average and relative space motions of a few km s^{-1}.

In Orion, the work by Kounkel et al. (2017) was one of the first studies that revealed the 3D structure of the cloud. Using VLBA data alone from GOBELINS, we found a distance gradient of about 40 pc between the ONC and L1641 and a similar value between NGC 2068 and NGC 2024. A prominent distance gradient of 30 pc from east to west was also found in the Perseus complex (Ortiz-León et al., 2018a) and a small distance gradient of 6 pc in Ophiuchus (Ortiz-León et al., 2018b). We also investigated the kinematical properties of the IC 348 and NGC 1333 clusters in Perseus (Ortiz-León et al., 2018a), finding that their internal motions are dominated by random motions, rather than by ordered motions due to expansion, contraction or rotation.

Finally, we derived the astrometry of water masers associated to a protostar in the very young ($\sim 2 \pm 1 \times 10^5$ yr) Serpens South cluster (Ortiz-León et al., 2023). No optical sources with good astrometric solutions were available in *Gaia* DR3. Thus, a direct distance determination was only possible thanks to the observations performed at radio wavelengths.

3. Astrometric Characterization of exoplanetary systems

Astrometric accuracy of tens of micro-arseconds (μas) has the potential to reveal the presence of hidden companions, which would induce a reflex motion on the star about the system's barycenter. Very Long Baseline Interferometry observations of the radio emission from nearby ($\lesssim$10 pc) low mass stars (M-dwarfs, ultracool dwarfs and brown dwarfs) have allowed us to search for companions with planetary masses. Using the VLBA, we discovered a Saturn-mass exoplanet associated to the ultracool dwarf TVLM 513–46546 (Curiel et al., 2020). This planet has a period of 221 $\pm$ 5 days and induces an astrometric signature (semi-major axis of the star's orbit) of 145 $\pm$ 20 μas.

We also performed VLBA observations of the M3.5+M4.5 binary GJ 896AB, detecting both components (Curiel et al., 2022). Fitting the positions of the primary star, including acceleration terms to take the perturbation of the secondary star into account, revealed significant residuals that suggest the presence of a new close companion orbiting the primary star. The absolute positions of the primary and secondary star, as well as the relative positions of the binary (from radio and optical data) were fitted simultaneously with a combined model that includes the new companion. We found a period of 284 $\pm$ 2 days and a mass of 2.3 $\pm$ 0.6 M_{Jup} for the planetary companion. The astrometric signature induced by the planet on the host star is 510 $\pm$ 150 μas. The true 3D orientation of the binary and planetary orbits is shown in Fig. 1. Using the angles obtained from the astrometric fittings we estimated a mutual inclination angle between the orbits of 148°.

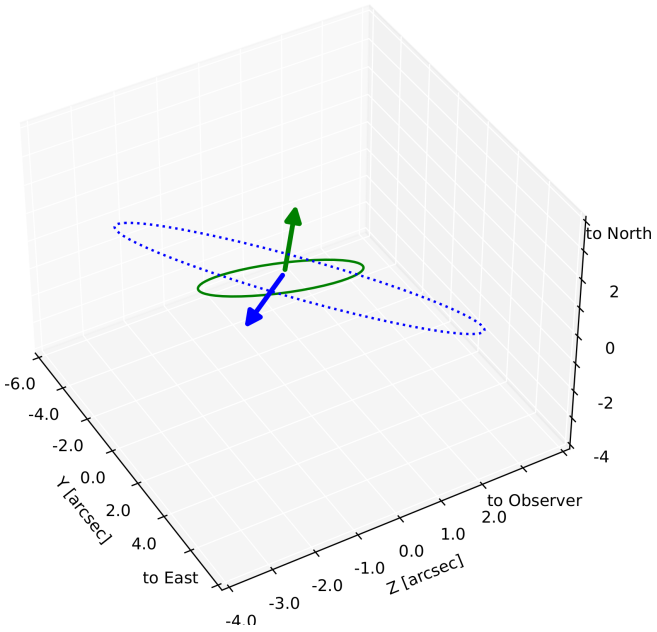

Figure 1. 3D representation of the binary (blue) and planetary (green) orbits in GJ 896. The arrows indicate the orbital angular momentum vectors. The planetary orbit has been scaled by a factor of 20.

4. FINAL REMARKS

Radio astrometry and *Gaia* have been fundamental for the characterization of molecular cloud 6D structure and the stellar systems that live within them. In the field of exoplanet exploration, high-precision astrometry is now making important contributions. The 3D shapes and the true inclination between planetary and binary orbits can be investigated. With more discoveries that next-generation instruments can bring, astrometry could help to better understand planet formation in single and binary stars and their dynamical evolution.

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Star membership in three nearby open clusters

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Keywords: *(Galaxy:) open clusters and associations: general astrometry, methods: statistical, methods: data analysis, stars: kinematics and dynamics catalogues*

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We carry out a star membership study in three nearby open clusters: Pleiades, Praesepe and Blanco 1, employing a Bayesian astrometric model with proper motions and an unsupervised clustering machine learning algorithm DBSCAN using positions, proper motions and parallaxes, all data from the Gaia Data Release 3 catalogue. The final membership lists are the crossmatch between results from both methods.

The Bayesian model uses two bivariate probability density functions: a circular for the open cluster $\psi_c(\mu_{\alpha*,i}, \mu_{\delta,i})$ and an elliptical for the field stars $\psi_f(\mu_{\alpha*,i}, \mu_{\delta,i})$ (Vasilevskis et al., 1958). These two densities can be collected in the joint probability function given by Eq. (1), which depends on nine parameters that were estimated via the maximum likelihood estimation and Markov chain Monte Carlo. We maximize the likelihood function given by Eq. (2), then, membership probabilities were computed using the Eq. (3).

$$\psi(\mu_{\alpha*,i}, \mu_{\delta,i}) = n_c\psi_c(\mu_{\alpha*,i}, \mu_{\delta,i}) + (1 - n_c)\psi_f(\mu_{\alpha*,i}, \mu_{\delta,i}). \quad (1)$$

$$\ln \mathcal{L}(\vec{\theta}) = \sum_{i=1}^{n} \ln \psi(\mu_{\alpha*,i}, \mu_{\delta,i}|\vec{\theta}). \quad (2)$$

$$P_i(cluster|\mu_{\alpha*,i}, \mu_{\delta,i}) = \frac{n_c\psi_c(\mu_{\alpha*,i}, \mu_{\delta,i})}{n_c\psi_c(\mu_{\alpha*,i}, \mu_{\delta,i}) + (1 - n_c)\psi_f(\mu_{\alpha*,i}, \mu_{\delta,i})}. \quad (3)$$

The DBSCAN algorithm (Ester et al., 1996) was applied in a five-dimensional astrometric space (α, δ, $\mu_{\alpha*}$, μ_δ, ϖ) computing distances using the Euclidean metric. We standardised data and in order to obtain the ϵ and $minPts$ with the best efficiency, first, we compute the k-th nearest-neighbour distance (k-NND) histogram of data and store the median value as ϵ_{kNN}. Second, generate random samples for data from a Gaussian kernel, compute the k-NND histogram and store the median as ϵ_{rand*}. An average of 30 repetitions was performed and ϵ_{rand} is the average of ϵ_{rand*}. Finally, the ϵ was determined as $\epsilon = (\epsilon_{kNN} + \epsilon_{rand})/2$ (see Fig. 1). We chose $minPts = 8$ for each cluster.

From the selected members, we fit the King model (King, 1962) to the radial density profiles in order to compute core and tidal radius (Alfonso & García-Varela, 2023). We also estimate age and metallicity from *Gaia* photometry using BASE-9 (von Hippel et al., 2006) and the PARSEC models (Bressan et al., 2012). These results were close to previous works, however, there are some differences for the tidal radius that may be a product of stretching in the spatial distributions because of coordinate transformations.

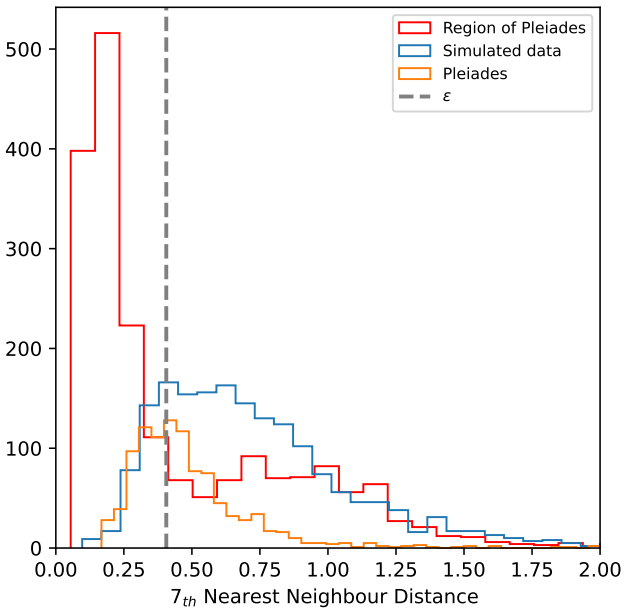

Figure 1. Histogram of the 7_{th}-NND for the region of Pleiades (red), simulated data (blue), and the Pleiades members selected from the PM model (orange). The grey dashed vertical line is the selected ϵ.

Acknowledgments: This work is part of the doctoral thesis of J. Alfonso and is funded by Facultad de Ciencias, Universidad de los Andes, Colombia.

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The benefits of extending the FRIPON-Chile Network to surrounding countries

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Keywords: *meteorites, meteors, meteoroids, instrumentation: detectors, methods: observational*

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FRIPON (https://www.fripon.org) is an acronym for *Fireball Recovery and Inter-Planetary Observation Network*. It is an efficient ground-based network of more than a hundred all-sky cameras mainly installed in France and dedicated to the observation of fireballs to characterize the extra-terrestrial matter falling on Earth, and determining the impact area for facilitating the recovery of freshly fallen meteorites. This network started in France in 2016 and has been extended first to Europe and Canada and more recently to Chile (https://www.fcla.cl/fripon-chile) for filling in the gap in the detection of these events in the southern skies and thereby obtaining an exhaustive view of fireball activity. In this talk, we will first introduce the FRIPON network with a special focus on its recent extension in Chile as well as a short report of the first detections we obtained from the southern hemisphere. Then we wil emphasize the necessity of extending the network to the surrounding countries of Chile for increasing the probability of meteorite recovery after meteor detection by the network.

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Secular and resonant effects generated by the hypothetical Planet 9

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Keywords: *celestial mechanics, minor planets, planets and satellites: dynamical evolution and stability, methods: numerical*

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The hypothesis of the existence of a planet with high eccentricity and inclination, not yet discovered, beyond the orbit of Neptune (called Planet 9), was developed by the authors Batygin & Brown (2016), to explain a series of anomalous dynamic behaviors in trans-Neptunian objects (TNO), such as the existence of objects grouped in their perihelion longitude ϖ, the distance of their perihelions from the Neptune region, or the existence of objects with a high inclination.

Viera 2023 (MSC Thesis) analyzes the validity and potential of using semi-analytical models for the study of secular and resonant dynamics generated by a disturber with high eccentricity and inclination, and its application to the Planet 9 hypothesis. We present here some of the relevant results.

Using a semi-analytic model the secular dynamics without limitations in (a, e, i) are studied, demonstrating that a disturber with high eccentricity and inclination is capable of reproducing the clusters in ϖ reported by Batygin & Brown (2016), for TNO with $a \geq 250$ ua. The parameters used for Planet 9 were: $m_9 = 10m_\oplus$, $e_9 = 0.6$ and $i_9 = 10°$.

By using a semi-analytical model for resonant dynamics, developed by Gallardo (2020), the characteristics of the resonances generated by Planet 9 are studied, the areas where they interact with the resonances of Neptune, and the generation of chaotic zones. The results are verified using dynamic maps (see Fig. 1).

We find that the resonances generated by an eccentric perturber are broad and depend weakly on the eccentricity of the particle (see Fig. 1).

Using numerical integrations, the secular dynamics within resonances for a period similar to the age of the Solar System are studied. It is verified that the resonant dynamics is capable of generating groupings in ϖ for the same values as the secular dynamics. It is shown that secular dynamics within resonances is capable of generating particles with high inclination for $a > 250$ au. The best observation conditions for these objects, that means lower q, occur for $\Delta\varpi \sim 90°$ y $270°$ and $i \sim 90°$.

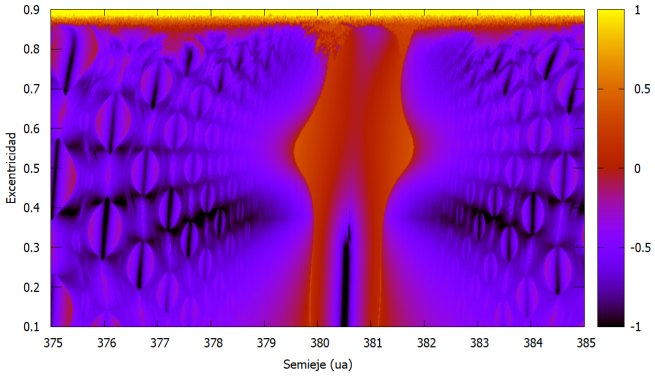

Figure 1. Dynamic map for test particles with 375 au $< a <$ 385 au and $0.1 < e < 0.9$ generated, including Neptune and P9. The main structure is the resonance 5:2 with Planet 9. The color indicates the variation of the semimajor axis on a logarithmic scale.

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The asymmetric sunrise effect on Thales' alleged measurement of the sun angular size

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Reports from the 2nd and 3rd Century AD attribute the first measurement of the angular size of the Sun to Thales of Miletus, in the 6th Century BC. Cleomedes, also in the 2nd Century AD, described a method to perform the measurement, based on timing the duration of the sunrise. Several modern authors have suggested Thales used Cleomedes' method, but others are skeptical of the connection. I present an objection that has not been discussed in the literature, namely, that the proportionality between the size of the Sun and the duration of sunrise is not constant, but changes with latitude and time of the year, due to what I call the "asymmetric sunrise effect". I show that this effect is large enough to have prevented Thales from obtaining the roughly accurate recorded value.

Please find a copy of the poster at https://jrcuadra.github.io/plaga/larim_thales/ or read the full-length paper at https://doi.org/10.1093/pasj/psad026.

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Unsupervised decontamination of field stars in color-magnitude diagrams of star clusters

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Knowledge of the fundamental parameters of star clusters is key to understanding the structure and evolution of galaxies. This is because star clusters are excellent tracers of the different galactic subsystems. In this work, we present an unsupervised method for decontaminating stars from the field in color-magnitude diagrams (CMD) of star clusters, developed in Python, which allows assigning statistical probabilities of membership to each star observed in the field of a star cluster.

The membership probability of a star to a star cluster is evaluated from the comparison of the properties observed in color-magnitude diagrams of the regions surrounding the cluster of interest and that of the cluster.

The method of cleaning the star clusters' CMDs consists in the implementation of a Python code that compares the CMDs of areas adjacent to the star cluster with the observed CMD of the cluster of interest. The stars removed from the observed cluster CMD are those closest to the field CMD stars. We perform this process with a thousand different adjacent fields and then estimate the membership probability of each star in the cluster based on survival in the elimination process.

This statistical method was applied to more than 30 star clusters in the Small Magellanic Cloud. This is the first step in order to determine their astrophysical parameters (e.g., age, metallicity and heliocentric distances), with the aim of analyzing their kinematics in the galaxy.

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The LLAMA radiotelescope: Present status, available instrumentation, and scientific perspectives

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Keywords: *telescopes, instrumentation: miscellaneous, instrumentation: detectors, radio continuum: general, radio lines: general*

The LLAMA Observatory, in the Argentinian Andes at 4800m altitude, in the Salta province, is a project of Argentina and Brazil, which started in 2014 with an agreement between FAPESP (research foundation of Sao Paulo State), University of São Paulo, and MinCyt (Ministry of Science and technology of Argentina). The expenses will be equally shared. The 12m diameter antenna was constructed by VERTEX Antennentechnik GmbH (Duisburg, Germany). The surface precision of the dish will reach 15 microns r.m.s. deviations from an ideal parabola, after a period of fine adjustments. The antenna will perform observations at mm and sub-mm radio waves, like the international ALMA interferometer. The LLAMA antenna will be equipped with two lateral Nasmith cabins, similarly to the APEX antenna. Initially, we will work with receivers for band 5, band 6 and band 9 (band names of the ALMA observatory), constructed at NOVA Labs (University of Groningen, Holland). Brazil contributed to the acquisition of part of the receivers and construction of sub-systems, like the optomechanical system to be installed inside the Nasmith and Cassegrain cabins, the cryogenics, and cryostat,where the receivers will be installed, and a system for holography.



Figure 1. The dish of the LLAMA Radio Telescope being mounted.

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The mounting of the antenna, which was slow in last years is going quite rapidly now, after Mincyt attributed to INVAP, a strong engineering and technological company, the task of mounting. It is predicted that the mounting will be concluded in March 2024, and the first light will happen 2 years later.

The main scientific uses will be in the following areas: Galaxy Formation in the Early Universe, Astrochemistry, molecular evolution of interstellar clouds and identification of unknown lines, extra-solar planets and proto-planetary disks, polarimetry of radio sources and of the Interstellar Medium, Solar Physics (few antennas at this frequency can be pointed towards the Sun, like LLAMA).

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BOCOSUR: An all sky network for fireball detection in Uruguay

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Keywords: *H II regions, ISM: jets and outflows, stars: pre-main sequence, stars: mass-loss*

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We present the BOCOSUR network, a set of 20 stations widely spread across the entire territory of Uruguay, for automatic detection of fireballs.

Meteorites constitute relics of the early formation of the Solar System. A rapid recovery of fallen material is essential in retrieving a fresh and unweathered sample, which, together with the determination of the meteoroid's pre-atmospheric orbit, can significantly constrain the conditions on its origin. The most cost-effective way of rapidly retrieving such material is through the deployment of automated networks for the detection of fireballs.

The BOCOSUR network is an initiative driven by the Department of Astronomy of the Faculty of Sciences of the University of the Republic of Uruguay (UdelaR), and comprises 20 stations of all sky systems for automatic detection of fireballs, focused on very bright fireballs of asteroidal origin that may give rise to meteorites. Most of the stations are located in secondary schools. The reason for this is that the project is intended to have a strong citizen science profile, involving teachers and students in the operation of each station.

The acquisition system is based on a ZWO ASI 178MM (Mono) camera, which has a 1/1.8" CMOS sensor (IMX178) and a 14-bit ADC. The sensor's peak quantum efficiency (QE) is 81%, and the highest available video resolution is 2080x3096 pixels.

All of the applications and scripts for camera control, calibration, data acquisition, data transfer and post-processing have been locally developed in MATLAB (applications) and Python (scripts). The application for camera control, calibration and data acquisition runs locally on each PC, and enables to set the most relevant camera properties. Additionally, an application for post-processing detected events allows to perform both astrometric and photometric calibrations, and apply them to a fixed (e.g. Moon, planets, stars) or moving (meteor) body on the video stream.

We carried out a comparison between the astro- and photometric performances of the ZWO ASI camera versus a widely used, low resolution camera (Watec 902 H2). The reason is that the latter is still widely used in different meteor networks. The mean absolute error (MAE) of astrometric calibrations were 15' and 5', for Watec and ASI, respectively. As for the photometric results, a 30s integration of Watec data yields a limiting magnitude (SNR≥5) of +2.79, while a 10s integration of ASI data gives a limiting magnitude of +3.18.

The data processing pipeline was applied to a very bright event detected by five of the southeaster most cameras of the network, yielding a peak absolute magnitude of -9.0 mag. The computed geocentric radiant was coincident with that of the Northern Taurids, associated with the comet 2P/Encke.

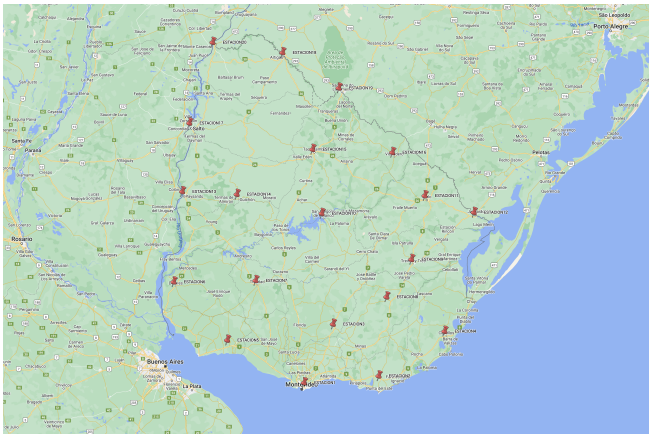

Figure 1. Location of the 20 stations that comprise the BOCOSUR network.

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In summary, we have succesfully deployed a nationwide network for automatic detection of fireballs, which contributes to unbias the geographical distribution of similar networks around the world. The data processing pipeline which has been developed enables to reconstruct the meteoroids pre-atmospheric orbit, and lays the ground for further developments which will enable to model the dark flight, essential to limit the search area of meteoric material.

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Semi-Supervised domain adaptation for multi-band Supernovae classification

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Keywords: *(transients:) supernovae, methods: statistical, methods: data analysis, techniques: photometric*

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We introduce a novel approach that extends the Minimax Entropy (MME) algorithm for the multiband photometric light curve classification of supernovae. We assess the performance of our classifier based on the number of objects provided during training, the number of observations during prediction, and the multiband capabilities of the top candidates. Our results demonstrate the effectiveness of our method in the early classification of Zwicky Transient Facility (ZTF) transients.

In this work, we utilize two datasets: transients obtained through the ALeRCE broker with forced photometry from ZTF and synthetic light curves (SLC). Both datasets include fluxes for type Ia, II, Ibc, and super-luminous supernovae in the *g* band ($\sim$ 464 nm) and *r* band ($\sim$ 658 nm), along with temporal information regarding the first alert per object.

We defined two sets of experiments: a *fine-tuning* strategy that involves taking a deep learning model previously trained with SLC data and further training it using a smaller labeled set from the ZTF sample, and a *domain adaptation* experiment through Minimax Entropy (Saito et al., 2019). This experiment utilized the full simulated dataset, a small number of labeled items from the ZTF sample, and an unlabeled dataset comprising the remaining ZTF objects. We optimized the model parameters via a two-term loss function:

$$\mathcal{L} = H(y_s, \hat{y}_s) + \lambda H(\hat{y}_u) \quad (1)$$

Here, the first term represents the cross-entropy loss between the true and predicted values, and the second term denotes the entropy of the predicted labels for the unlabeled dataset.

The results for various sequential models (Muthukrishna et al., 2019; Bai et al., 2018; Astorga et al., 2023) on the 15th day after the trigger, sorted by ZTF objects delivered during training, are presented in Table 1. The Temporal Convolutional Network (TCN) proves to be the most suitable for classification, outperforming the Recursive Neural Network (RNN) and the Transformer (TLC). The MME algorithm is the most effective, requiring only five ZTF objects per class during training, surpassing fine-tuning (FT), which needs a minimum of ten objects. When evaluating the top TCN clasiffiers on the SLC dataset on the 15th day after the trigger, MME achieves 52±3%, outperforming FT (51±3%) and remaining competitive with the fully-trained TCN on SLC data (55±1%).

Table 1. Metric score, 15th day after the first alert.

Shots	Train	F1-Score(%)		
		RNN	TCN	TLC
1	FT	49±8	52±2	39±7
	MME	49±7	54±7	27±4
5	FT	50±5	51±4	44±5
	MME	49±7	**55±3**	41±5
10	FT	49±6	**55±3**	**46±4**
	MME	54±6	55±5	36±7
15	FT	**52±5**	53±3	44±7
	MME	**55±2**	51±7	37±5
20	FT	44±4	51±7	40±2
	MME	50±7	50±6	**38±2**

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What is this? WIT objects and other serendipity discoveries in the VVV/VVVX survey

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Keywords: *stars: variables: general, transients: general, infrared: stars, astronomical data bases: surveys, Galaxy: stellar content*

The WIT objects (short for What Is This?) are sources that defy classification found in the near-IR database of the VISTA Variables in the Vía Láctea (VVV) survey and its extension the VVVX survey. Here we summarize some specific cases of these previously unclassified variable sources.

We have been monitoring the Galactic bulge and southern disk in the near-IR using the VISTA telescope at ESO Paranal Observatory since year 2010. Massive searches for variable stars have been carried out in this vast database, resulting in the discovery of $> 10^6$ variables, including eclipsing binaries, RR Lyrae, Miras/LPVs, δ Scuti stars, classical Cepheids, type II Cepheids, novae, microlensing events, etc. These catalogs of variable stars have wide applications for studies of stellar populations, stellar formation and evolution, star clusters, and Galactic structure (e.g., Ferreira Lopes et al. 2020, Navarro et al. 2020, Herpich et al. 2021, Molnar et al. 2022).

Interestingly, within our database we have also found some objects that defy classification, and therefore we labeled them as WIT objects. Upon closer inspection, in the end some of the candidate WITs turn out to be observational glitches. Some of them appear fit into the previously known kinds of objects, but that are observed through extreme conditions like very high extinction. However, a few of them appear to be manifestations of new astrophysical phenomena, with light curves that exhibit unique peculiarities. These WIT objects represent a wide variety of extreme or rare sources, including for example:

• VVV-WIT01, a very reddened novae or supernova or a protostellar collision (Lucas et al., 2019).

• VVV-WIT04, an extragalactic radio source violently variable in the near-IR (Saito et al., 2019a).

• VVV-WIT06, an extreme infrared transient as a probable dusty nova (Minniti et al., 2018).

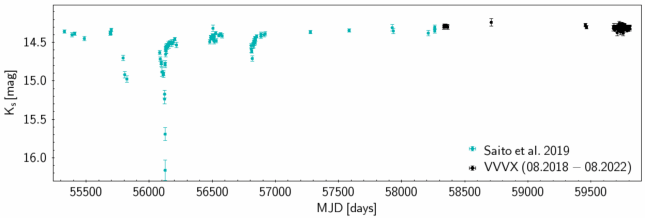

Figure 1. Ks-band light curve for VVV-WIT07 covering a 12-year baseline, including VVV and VVVX data.

• VVV-WIT07 (Figure 1), that is likely another Tabby star or Mamajek object (Saito et al., 2019b).

• VVV-WIT08, a disappearing source, nicknamed 'the giant that blinked' (Smith et al., 2021).

• VVV-WIT12, an unusual long period source that induces variability in its surrounding nebula, probably a light echo (Saito et al., 2023).

New classes of variable stars emerge, as illustrated by the discovery of the dipping giants (Lucas et al., 2024). They constitute a population of aperiodic late-type giant stars with extreme variability, that suggests the presence of deep extinction events. They are strongly clustered in the nuclear disc of the Milky Way, suggesting that they are very metal-rich giants undergoing high mass loss.

In most cases spectroscopic follow-up observations are needed to properly characterize the rare sources. These WIT objects, some of which were initially serendipitous discoveries, are now subject to a more systematic search in the rich VVVX database. Our work also underscores the need to take into account serendipity in future large surveys. To placate some critics, we note that these are not mere fishing expeditions, because new science is emerging…

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Radio telescopes for Mexico and Latin America

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Keywords: *telescopes instrumentation: miscellaneous, radio continuum: general, techniques: interferometric masers*

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Inspired by efforts in Asia, Australia and Africa, we have undertaken the conversion of a retired telecommunications antenna into a radio telescope. The Tulancingo-1 antenna is a 32-meter parabolic dish, located at the Tulancingo Earth Station in the Mexican state of Hidalgo. When fully operational, we anticipate a useful frequency range from 1 to 15 GHz, and possibly as high as 23 GHz. Here, we describe the current state of the conversion project, mention several of the many potential science applications, and extrapolate our experience to what might be achieved by a Latin American network of radio telescopes, based on similarly converted antennas.

After extensive work by the metrology team of the INAOE and technicians from the San Pedro Mártir Observatory operated by the UNAM, the Tulancingo-1 antenna is now ready for commissioning, which we expect to last for most of the 2024 calendar year. The development of a pointing model and overall testing of the telescope will be carried out with an L-band receiver covering 1400 to 1800 MHz. After this initial commissioning, we plan to install a cryogenic C-band receiver, and also to make test observations with a warm K-band receiver. Early science applications will include maser and AGN monitoring observations.

Through the *Iniciativa VLBI Ibero Americana* (IVIA[1]) we have contacted researchers throughout Latin America and identified a number of retired telecommunications antennas that might be suitable for conversion. As these radio telescopes come on-line, our long-term goal is to equip them for VLBI observations and thus involve Latin America in global centimeter-wave VLBI projects.



Figure 1. Front view of the 32-m Tulancingo-1 antenna. The electro-mechanical work for the conversion to a radio telescope is largely complete; commissioning will commence in 2024 using an L-band receiver.

[1] https://oaq.epn.edu.ec/ivia-net/index.php/es/

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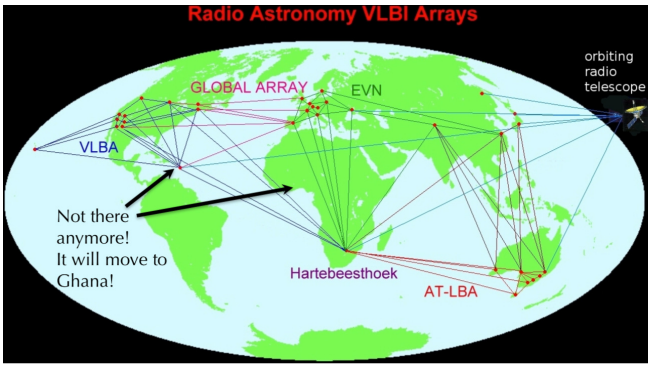

Figure 2. The map shows existing centimeter-wave VLBI networks. With the collapse of the Arecibo telescope (and the coming-online of the Ghana telescope) existing baselines will shift further eastward. Central and South America is the most notable region without cm-VLBI coverage. The IVIA effort seeks to bring Latin America into the global cm-VLBI fold.

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Proliferation of nighttime artificial lighting and light pollution in major urban areas of Latin America

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Light pollution is a form of environmental degradation that is increasing worldwide and affecting the natural environment, flora, fauna, and various aspects of human life. Despite growing concern about this issue, its study is still limited in Latin America. In this research work, we conducted a comprehensive analysis of the expansion of artificial night light in major Latin American urban centers between 2012 and 2022. The study focused on the cities of Ciudad de Mexico, São Paulo, Bogota, Lima, Santiago, Buenos Aires, Rio de Janeiro, Caracas, San Jose, Havana, Quito, Asuncion, Montevideo, and La Paz. The data reveals a wide range of radiance growth rates across the surveyed cities. While Asuncion and Lima experience significant annual radiance increases (4.55 and 6.84, respectively), Caracas shows a notable decline (-2.28). This disparity suggests diverse trajectories in urban lighting practices. Cities like Santiago de Chile and Buenos Aires show substantial increases in the illuminated area (847 km^2 and 547 km^2, respectively). Conversely, cities like Caracas and La Habana demonstrate a reduction in illuminated areas. These findings provide valuable information on the growing threat of light pollution in Latin America and supports the need for action to help control associated environmental degradation. It is essential to raise awareness of the negative impacts of light pollution on the ecosystem, human health, and astronomical observations. Implementing lighting regulations, promoting energy-efficient lighting technologies, and incorporating light pollution considerations into urban planning are essential steps to mitigate the effects of light pollution and protect the natural environment in major Latin American urban centers.

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Towards a first sectro-photometric characterization of the Chilean night sky

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Light pollution is widely recognized as a global issue that, like other forms of anthropogenic pollution, has significant impacts on ecosystems and adverse effects on living organisms. In recent years, it has emerged as a fertile field for interdisciplinary scientific research, socioeconomic studies, and wide-ranging cultural debates. Chile is widely known for its rich and distinctive ecosystems, and the superb quality of its northern skies has transformed it into one of the most important astronomical nodes in the world. Nevertheless, a coordinated scientific approach to characterize, quantify and monitor the effects of ALAN on the Chilean sky has only recently started. Our interdisciplinary research group on ALAN was born five years ago with the explicit purpose of filling this need, and aims at providing the international community with the first spectro-photometric characterization of one of the most pristine skies of planet Earth. Since 2019 we have been regularly monitoring more than twenty distinctive sites across the Coquimbo Region (also known as "Región Estrella"), including professional astronomical observatories, astrotourism centers, natural parks, and metropolitan areas. In this poster contribution we will introduce our research group by describing its raison d'être; stating its short, medium and long-term goals; and presenting the first results of our surveying campaigns. We further describe how our scientific projects and outreach initiatives, through a constant synergy with public and private institutions, contribute to heighten public awareness about the subtle but devastating effects of light pollution. Finally, we offer an example where our scientific conclusions have supported different public committees in taking more enlightened decisions to preserve the darkness of the Chilean sky, a natural and cultural heritage that is our scientific, moral and social obligation to protect and defend for all future generations.

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Research and development of sonification tools for astronomical and astrophysic data: the case of sonoUno

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Data analysis in space sciences has been done exclusively visually for many years, even when there is evidence that more than one sensory style is possible (as is with sonification). Maintaining the data analysis exclusively visual not only limits the study of the unknown to the current resolution of the screens but also excludes a group of people who present different degrees of visual impairment. Considering those above and the fact that people with functional diversity experience a large number of barriers to achieving higher education and stable jobs, within the framework of my doctoral thesis, a new modality to access scientific data from the space sciences was investigated[1]. SonoUno is a product of this research that makes possible a multisensory display (use of more than one sense) of data files with two or more columns, taking into account the accessibility and inclusion of people with functional diversity from the beginning[2]. Based on the fact that multisensory perception can be a good complement to visual exploration for the understanding of complex scientific data and the exchange and feedback received from users over the past six years, sonoUno presents a framework focused on the user and is an application that can be used independently on the computer or through a web page. Additionally, the package presents different scripts for specific sonifications and use in bash. The work presented here maintains the next fundamental pillars: providing solutions and removing barriers (in education and scientific work, up to now); the use of free programming languages; and the design of infrastructure to improve inclusion.

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[1] https://arxiv.org/abs/2305.05635
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Massive photometric catalogs for S-PLUS: object classification and quasar photometric redshifts

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The Southern Photometric Local Universe Survey (S-PLUS; Mendes de Oliveira et al. 2019) will cover 9300deg2 of the Southern Sky with an 80-cm telescope (T80S) located at Cerro Tololo Inter-American Observatory in Chile. The S-PLUS optical filter system includes five broad bands: u, g, r, i, z (similar to the SDSS filter system, except for the u band) and seven narrow-band filters: J0378, J0395, J0410, J0430, J0515, J0660 and J0861, centred on [OII], Ca H+K, Hγ, G-band, Mgb triplet, Hα and Ca triplet features, respectively. The latest public data release (DR4) covers 3000 squared degrees.

In this work we detailed the construction of two value-added catalogues for S-PLUS DR4: the star/quasar/galaxy classification and quasar photometric redshifts. The former was obtained by a Random Forest algorithm that classifies any S-PLUS observation in quasar, star or galaxy. A complete description of all tested feature spaces, metrics, cross-validation, and performances on S-PLUS DR2 can be found in Nakazono et al. (2021). For the quasar photometric redshifts we use data from S-PLUS DR4 in three machine learning methods: Random Forest, FlexCoDE, and Bayesian Mixture Density Network. FlexCoDE had the best performance with a precision of 0.042 and conditional density estimation loss of -2.84. Using the information from these two value-added catalogues, we then provide a catalogue of quasar candidates (Nakazono & Valença, submitted) containing 626 418, 220 177, and 131 376 quasar candidates with probabilities higher than 80%, 90%, and 95%, respectively.

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Evaluation of the impact of artificial light on the nocturnal landscape and soundscape of Las Brujas (Canelones, Uruguay)

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Increasing the emission of artificial light at night has well-documented negative effects on the quality of natural dark skies and changes the natural light/dark cycles, on which many species depend. Dark skies are relevant as natural values and for their cultural and heritage significance. This issue is just beginning to be perceived as a problem by decision makers and the civil society. The present work is a response to the concern of residents of Las Brujas (Canelones, Uruguay) regarding public lighting installation in July 2022. This research analyzes the nocturnal landscape before and after the placement of public lighting and its impact over the natural soundscape. Soundscapes are defined as the set of sounds generated by the elements that compose an environment. Through soundscape analysis, it is possible to estimate the response of organisms to anthropogenic pressures and to account for the structure and dynamics of the environment. For analyzing the nocturnal landscape, the sky brightness was measured at impact and control sites using an SQM photometer. From measurements obtained at 17 sampling points, sky brightness maps before and after the impact were made. For the analysis of the soundscapes, a Before-After, Control-Impact sampling design was implemented. A passive acoustic monitoring (PAM) was carried out, in which the soundscapes of 5 sites (1 impacted and 4 control sites) were recorded before and after the implementation of the new public lighting. By performing an analysis of variance, significant differences were found in the sky brightness before and after the public lighting was operational. However, the analyzed acoustic data shows that there are no significant variations in the acoustic landscape despite the alteration of the nocturnal landscape. Hypotheses that can explain this phenomenon are discussed and recommendations for the management of the socio-environmental problem are proposed.

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La Serena school for data science: Applied tools for data-driven sciences

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Keywords: *astronomical data bases: surveys, methods: data analysis, methods: statistical, software: data analysis, sociology of astronomy*

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The volume and complexity of astronomical data continues to grow as the current generation of surveys come online (PanSTARRS, Gaia, Dark Energy Survey, VISTA). Astronomers will need to work with giga, tera and even petabytes of data in real time (LSST). This poses the challenges of developing and using new tools for data discovery, access, and analysis. At the same time, there are new opportunities for interdisciplinary research in applied mathematics, statistics, machine learning, crowd-sourcing, etc. Astronomy provides a sand-box where scientists can come together from diverse fields to address common challenges within the "Big Data" paradigm.

In response, since 2013 the AURA-O/NOIRLab together with other Chilean organizations such as the ULS and Universidad de Chile, have implemented the "La Serena School for Data Science: Tools for Data-Driven Sciences". In this contribution we present our initiative, which is developed annually at the AURA campus in La Serena, Chile. Between July and August, the school receives 32 students and 10 expert professors for 10 days, following an intensive program of introductory classes with an important component of hands-on learning. This is materialized mainly by the development of group projects, where students solve complex problems in groups, applying what they have learned and guided by the teachers. Participants come from various countries such as the US (NSF-funded), Chile, and other Latin American countries such as Ecuador, Brazil, Mexico or Colombia. Students from different disciplines are encouraged to participate, including (but not limited to) astronomy, physics, computer science, statistics, mathematics, biology medical informatics.

Since LSSDS began 10 years ago, we have trained more than 230 students in data science. As seen in the statistics, efforts have been made to promote diversity in all possible areas. Also, the alumni of the school has been particularly active not only "returning" as Teaching Assistants, but also replicating parts of their schools at their home institutes.

The interest of the scientific community is increasing, with a record of applicants in the last year, mainly from Latin American countries.

We are very pleased to announce that the NSF has just approved the budget to fund LSSDS through 2024. [1] We invite all Latin American institutions to support this initiative!

Acknowledgements

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[1]Additional information and applications: http://www.aura-o.aura-astronomy.org/winter_school/

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RMxAC REVISTA MEXICANA DE ASTRONOMÍA Y ASTROFÍSICA SERIE DE CONFERENCIAS

Bridges between cultures: Astronomy as universal language

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Keywords: *history and philosophy of astronomy, sociology of astronomy, instrumentation: miscellaneous*

To commemorate the UNESCO International Day of Light (IDL), NASE proposes to carry out experiences of great educational interest and big impact. Although the IDL is May 16th, the activities can be perform between March and September equinoxes.

Throughout history, Astronomy marked the lives of human beings in diverse ways. The approach to the starry sky was important from the ritual and daily ceremonial point of view and occupied a good part of the activity of all people on Earth. Although we have fragments of knowledge of the peoples of the past, we know that astronomy allowed us to establish patterns that became part of universal culture: compass, clock, calendar, intangible heritage of humanity, according to the UNESCO declaration of 2007. Bridges between cultures, is the annual proposal of the Astronomy Education Network in the School (NASE) associated with the UNESCO call for May 16th, the International Day of Light. This activity aims, hand in hand with universal astronomical themes, ancestral knowledge, discoveries of the modern era and great challenges of science dedicated to the study of the "light" that arrives from the Cosmos, to reestablish the links that identify us as a species. The idea started in 2018 and the invitation to people all over the Globe is to perform a simple activity which connect them with the nature, using astronomical instruments.

The topics along the years were: detecting the invisible, measuring the power of the Sun, working with the parallel Earth, determining the Latitud (Ros & García 2022; Figure 1) and looking for micrometeorites (Ros & García 2023; Figure 2).

Every year, more than a hundred teachers participate, several hundred reports are sent from more than 200 students (5-18 and college), who come from more than 25 countries around the world.



Figure 1. Determining the latitud, Iran, 2022



Figure 2. Looking for micromeorites, China, 2023

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The indicators that allow evaluating the impact of the activities proposals and the testimonies of participants who constitute diverse audiences that come, many times for the first time, to the discipline that, without a doubt, confirm that astronomy is a universal language, which even allows us to write our stories in and thanks to the stars.

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Frontier Astronomy. Activities from the Perimeter Institute and the ICTP-SAIFR for the secondary classroom

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Keywords: *history and philosophy of astronomy, publications, methods: miscellaneous, cosmology: observations, gravitational waves*

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"Frontier Astronomy" and "Frontier Physics" are a series of activities for the highschool classroom that aim to share teaching techniques and strategies for the inclusion of modern and contemporary astronomy topics in the classroom, both in face-to-face classes and online. The activities are designed to be easily attached to regular physics or astronomy courses, without the need to change the curriculum, including motivating topics for students, addressing current issues such as dark matter, exoplanets, the expansion of the universe, cosmology, black holes, gravitational waves, among others.

The almost 100 activities, included in 18 books, were developed by the renowned Perimeter Institute for Theoretical Physics of Canada, and translated and adapted into Portuguese and Spanish by the ICTP-SAIFR (South American Institute for Fundamental Research), a physics center associated with Abdus Salam ICTP (Trieste , Italy) and associated with the Institute of Theoretical Physics of the University of São Paulo, Brazil (IFT-UNESP).

Each activity includes: a sequence of practices and related questions for discussion of activities in small groups; and an evaluation to consolidate learning.

The activities translated into Spanish began to be disseminated in March 2021 to physics teachers from Latin America through virtual workshops (Figure 1), organized by the ICTP-SAIFR and coordinated by Ana Luiza Serio. Since then, 47 virtual meetings lasting more than 2 hours have been held, reaching a total of 1339 participant entries from 20 countries.

Although the activities were adapted to virtuality, they were originally designed and are ideal to be carried out in face-to-face activities. Figure 2 shows an example of an activity on gravitational waves carried out in Montevideo for physics and astronomy teachers.

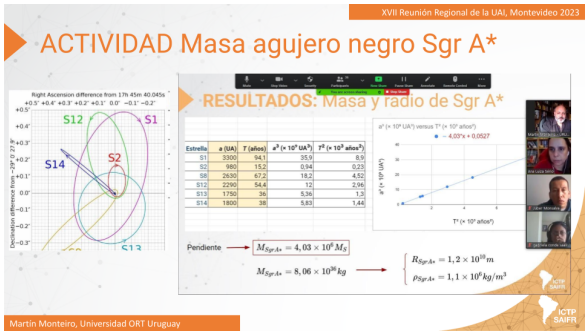

Figure 1. Screenshot of one of the virtual activities on black holes, in which the mass of Sgr A* is determined from the orbits of some of its satellite stars.

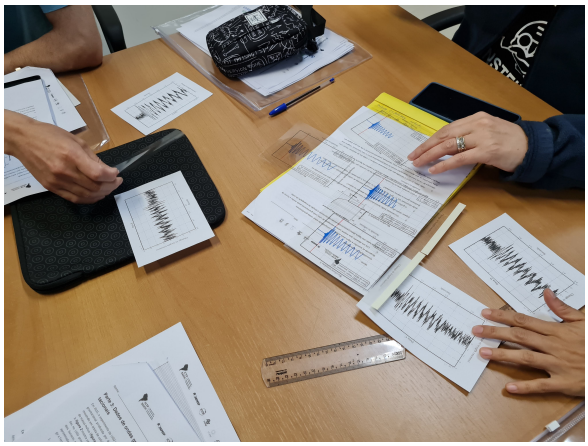

Figure 2. An in-person activity on gravitational waves. Students use transparent templates with different waveforms to compare them with theoretical models.

Finally, we encourage teachers to join the workshops and adapt the activities to the needs of their own classes.

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A digital game to teach stellar nucleosynthesis: design and student feedback

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Keywords: *nuclear reactions, nucleosynthesis, stars: evolution, astrochemistry, methods: data analysis*

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The use of digital technologies combined with an interdisciplinary approach that connects the periodic table to astronomy can provide students with a better understanding of the stellar nucleosynthesis of chemical elements, and thus motivate them to study these subjects. This work presents an educational digital game entitled "The Periodic Table According to Cosmochemistry", developed to playfully approach the synthesis of chemical elements in the context of astronomy.

At the beginning of the first phase, the player should capture a proton and throw it towards another one to produce a deuteron, a positron and a neutrino. Next task is to capture a deuteron and throw it towards a proton to synthesize a helium-3 nucleus. Each time a new chemical element is synthesized, the player sees a drawing with a brief description of that element, which is then placed on a periodic table. This phase ends when the player synthesizes the other elements of the proton-proton chain: lithium, beryllium and boron. In the second phase, the player goes through the triple-alpha process, the CNO cycle and the carbon-burning process. Finally, the last phase corresponds to a supernova explosion, in which heavier elements are synthesized.

Written in Python, the game is currently available in English and Portuguese (Siqueira, 2023) and can be freely downloaded from https://sites.google.com/site/credianafaria/. In order to evaluate the effectiveness of the game, we conducted teaching sessions at different school levels to investigate students' learning and perception about the game. These sessions involved 52 students, which were enrolled at an elementary school (12 students), a high school (8 students) and a university (32 students). In each session, students answered a questionnaire containing open and multiple-choice questions, played the game and answered the questionnaire again. The answers were then analyzed qualitatively and quantitatively, so that we could compare the answers before and after playing the game.

Table 1. Undergraduate students' feedback

Component	N	N_i
Motivation	11	2
User experience	17	9
Learning	3	2

The undergraduates also answered a questionnaire adapted from an educational game evaluation model developed by Savi et al. (2011), which consists of 3 subcomponents (motivation, user experience and learning), comprising 15 dimensions, 29 standard items and 3 customized items. The learning subcomponent includes customized items, which address the first three levels of Bloom's revised taxonomy: remember, understand and apply (Anderson & Krathwohl, 2001). The feedback pointed out the strengths and weaknesses of the current version of the game and provided suggestions for future improvement. A summary of the results can be found in Table 1, which shows each subcomponent, the total number of items N and the number of items that need to be improved N_i.

The qualitative and quantitative results provided evidence that this game is an effective educational resource, capable of motivating students, promoting learning, and providing a positive gaming experience. The use of educational digital games, such as this one, can be a promising approach to improve the teaching of stellar nucleosynthesis and the origin of the chemical elements. By integrating astronomy, chemistry, nuclear physics, and digital technologies, educators have the opportunity to spark students' interest and encourage their pursuit of knowledge in a meaningful way.

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Analog simulation to explore and teach exoplanetology concepts

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Keywords: *exoplanets, instrumentation: miscellaneous, methods: data analysis, planets and satellites: detection, techniques: photometric*

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In this work we present a proposal of analog simulation that allows to generate light curves for simple simulated exoplanetary systems, in transit with the purpose to use this resource to explain how to know from the analysis of the light curve, the semi-major axis, orbital period and reason of exoplanet/star sizes from an exoplanetary system. The assembly is set up for two exoplanetary systems, referred to: System A System B, obtaining a margin of error in their sizes estimation of 1.5% for system A and 4.25% for system B. The frequency spectrum of the time series for both systems leads to a reliable estimation about the traslation period for both of the systems arranged in the assembly. The high sampling rate of the light sensor incorporated in an average cell phone (100 ms), allows to make a test scaling 1 second = 1 day, in order to bring the framework of the test proposal in line with the scientific data in the study of exoplanet light curves. Due to the uncertainty of the fluxes measured for each light curve obtained (≈ 1e-7 lx), the setup is efficient and could be used to develop more rigorous investigations taking into account better analysis criteria (a ratio of star sizes/exoplanet more concordant with known exoplanetary systems), and better controlled laboratory conditions, in addition to being a low-cost proposal.

This proposal seeks to replicate, within a controlled indoor environment, the light curve readings of uncomplicated exoplanetary systems. Specifically, we aim to simulate Keplerian systems characterized by zero eccentricity and orbital inclination, utilizing the light sensors typically found in mobile devices, through the mobile application Arduino Science Journal (ASJ).

The assembly provides calibration details for an astronomy teaching proposal, aligning with scientific processes for determining measurable properties of real exoplanets via the planetary transit method. By modifying assembly parameters, real exoplanetary systems can be modeled, using more sensitive sensors with a minimum sampling time interval of 1 ms. The setup's efficiency, reflected in low error percentages (1.5% and 4.25%) for determining exoplanet sizes, allows for analogous simulations of exoplanetary systems.

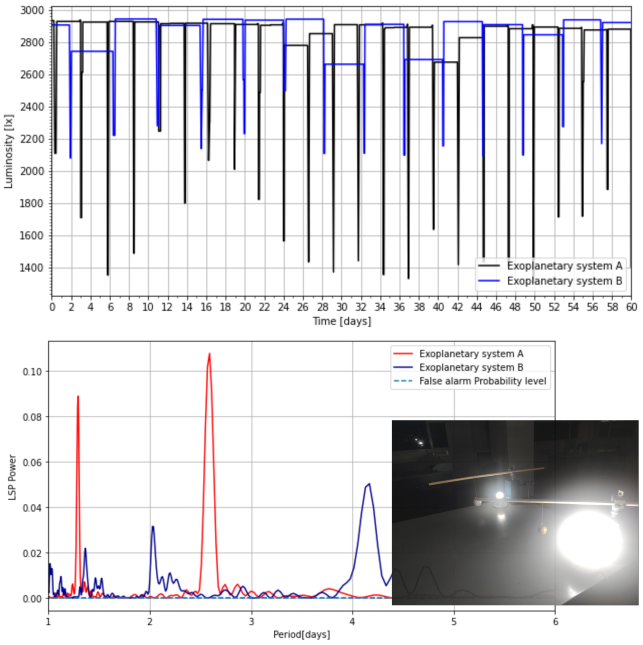

Figure 1. Up: Light curves of systems organized in the montage under the parameters: same star, different orbital speeds of translation, and 2 exoplanets of different sizes. Down. Frequency spectra obtained for each exoplanetary system. Bottom right: Final assembly photography.

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Teaching astronomy with ASTROLAB at PUCP

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Keywords: *open clusters and associations: general, stars: variables, telescopes, virtual observatory tools*

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We present our experiences teaching an introductory-level astronomy course at the Pontifical Catholic University of Peru (PUCP). Students attended theory sessions alongside practical experiences observing remotely using the Las Cumbres Observatory 40 cm telescopes https://lco.global/. This was done using the ASTROLAB (Starlight in the university lab) tutorial, a project of the Office of Astronomy for Development (OAD) of the IAU https://www.astro4dev.org/astrolab-starlight-in-the-university-lab/. With this effort, we try to make up for the few opportunities that undergraduate Peruvian students have to do observational astronomy, due to the limited number of astronomical facilities that exist in the country.

Students taking the course are introduced to methods of scientific research as they go through the same steps astronomers do when preparing and performing an observing program. They learn how to plan observations, submit proposals, process their data and analyze their results using astronomy software and Virtual Observatory (VO) tools on images obtained from the remote telescopes at Las Cumbres Observatory. This experience teaches students to develop teamwork abilities, understand the complexity and ambiguity of empirical work, develop practical skills, learn to perform error analysis, defend their results both in written and oral form, and most importantly: develop critical thinking.

This course was taught in three separate semesters between 2021 and 2023. Individual and group-based observation and analysis projects focused on a series of different observable astronomical objects and phenomena. Observations took the form of photometric (B, V, rp) images, due to the instruments we had access to from the Las Cumbres Observatory network. The analysis performed was primarily aperture photometry, although the mechanism to perform the analysis changed between semesters as the course developed, from pre-written Python algorithms the students had to manipulate to use of the IRIS software. Projects ranged from creating lightcurves of eclipsing binary stars, making color-magnitude diagrams of open clusters, identifying asteroids, and even obtaining a lightcurve of the recent supernova in M101, SN2023ixf; in each case students had to not only understand the nature of the scientific analysis to be performed, but also understand observational constraints and perform target selection.

By being exposed to a variety of kinds of objects, which behave very differently from an observational standpoint and thus require different modes of analysis, the students were able to be exposed to a wide panorama of the kinds of research done in astronomy, even while restricted purely to optical photometry. Individual and group reports of each project were submitted to the instructor for grading and feedback purposes.

This work makes use of observations from the Las Cumbres Observatory global telescope network (program LCOEPO2018A-001).

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First Andean Network of entrepreneurs in Astrotourism

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Keywords: *astronomical data bases: miscellaneous, methods: miscellaneous, sociology of astronomy*

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It is inspiring to see how astronomy is being used to foster development and improve local conditions in various regions, including those with challenging weather conditions such as the Andean Region in Latin America. In this contribution we describe the main goals of the first andean network of entrepreneurs in astrotourism and possible roles that professional and amateur astronomers could play in it.

Despite being one of the most cloudy regions around world and thus not very suitable for conducting optical astronomical observations, in countries as Ecuador, Colombia, Perú, Venezuela and Bolivia the interest on Astronomy has been growing during last two decades. This interest is not only to a professional level of formation but also it is related to some rural communities searching for improvemement of their own local conditions through sustainable projects that make use of astronomy. Pionner OAD projects such as “Astronomy for Himalayan Livelihood Creation" have shown how digital education, energy access to remote unelectrified communities and in general, an improvement of local conditions can be reached through astronomy[1].

With the aim to promote responsible and innovative tourism of stars in the Andean region, especially in rural areas in which it could become a real driving force for local economies, the OAD and EPN (Ecuador) organised the IV Workshop Astronomia en los Andes : “Engaged communities in development through Astrotourism” held in Quito in October 2023. Almost seventy entrepreneurs from 4 andean countries were sharing experiences with experts. An important outcome of this meeting was the creation of the **First Andean Network of Entrepreneurs in Astrotourism**, a platform for dialogue between entrepreneurs and experts aimed to avoid misconceptions in astronomy and to reaches communities with a clear explanation about how science and particularly astronomy works.



Figure 1. First Andean Regional meeting on astrotourism in Quito during October 2023

[1] https://www.astro4dev.org/category/astronomy-for-himalayan-livelihood-creation/

One important task of the first andean network is to enrich the experiences and practices through meetings with astronomy students, amateur and professional astronomers. As well as collaborations, the network requires support from initiatives such as the Network for Astronomy School Education - NASE[2]. It's truly fascinating how astronomy can be used as a tool for development, education, and economic growth. These initiatives are demonstrations of the power of science in transforming communities and improving livelihoods.

[2] https://www.naseprogram.org/es/

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Protoplanet express, a video game based on hydrodynamical simulations

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https://doi.org/10.22201/ia.14052059p.2026.60.24

High-resolution observations obtained during the last decade show that protoplanetary discs can be very complex objects. Rather than uniform discs, we see that they have large cavities, spiral arms, rings, gaps, and asymmetries. To understand these features, astrophysicists many times have to develop numerical simulations, in which planets or unseen stellar companions are added to reproduce the observed morphologies. While the spectacular observed images are popular in mainstream media, the simulation side is rarely known by the general public.

We have created "Protoplanet express", a video game in which the user visits different known protoplanetary discs, which are rendered in 3D from actual hydrodynamical simulations. The user will encounter in the models the same features observed with ALMA and other telescopes, and their goal will be to find the reason for each of them. For example, the user completes a level once they find the planet causing an observable gap in the disc.

Please find a copy of the poster at https://jrcuadra.github.io/plaga/larim_ppe/ and a related article at https://arxiv.org/abs/2303.17654. The game is available at https://store.steampowered.com/app/2601120/Protoplanet_Express/

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Astronomy and non-formal education as promoters of scientific literacy: the case of the Rodolpho Caniato astronomical pole

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https://doi.org/10.22201/ia.14052059p.2026.60.25

Astronomy is one of the Sciences that most causes fascination and curiosity in the general public, and thus, it can be used as a gateway to motivate the interest and participation of students and the general community in the scientific enterprise, thus enhancing the formation of scientifically literate citizens. , capable of making critical decisions about the world around them. As a way of working towards this cause, the use of Non-Formal Education spaces becomes an interesting alternative. In this sense, as a way of exemplifying how this relationship between Astronomy and the formation of scientifically literate citizens occurs, this work presents an overview of the activities and research in teaching carried out within the scope of the Rodolpho Caniato Astronomical Pole, located at UTFPR Campus Campo Mourão, Brazil, to which scientific literacy indicators are associated and discussed.

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Proposal for teaching astronomy in Brazilian middle schools based on Gagné's learning theory

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Qualified teaching of Physics requires alignment between a learning theory (psychological, descriptive) and grounded methodologies (SILVA FILHO; FERREIRA, 2009). Gagné's theory, developed in the transition between behaviorists and cognitivistsduring the behaviorist AND cognitivist transition (MOREIRA, 2022), frames learning as hierarchical information processing. This structure involves: **a. Discrimination** (distinguishing stimuli), **b. Concepts** (classifying objects), **c. Rules** (applying symbols like math), and **d. Higher order rules** (problem-solving). A Brazilian high school Astronomy course (13 hours, six modules) operationalized this theory through nine instructional events, focusing on gravitation via reflective, theory-guided activities. Students synthesized learning by creating mental maps, analyzed using Novak and Gowin (1984) criteria: concept hierarchy, thematic scope, original ideas, and technique application. Results demonstrated that most students successfully organized concepts and established relational dependencies. The integration of Gagné's theory with the methodology promoted hierarchical, meaningful learning with critical and interdisciplinary components. Key indicators-autonomy, conceptual relationships, and hierarchy-validated the approachs effectiveness, supported by complementary epistemological and methodological frameworks. This case underscores the value of theory-driven pedagogy in fostering structured, engaged learning.

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Astronomical outreach activities at the Observatorio Astronómico Los Molinos

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In this poster we present the different outreach activities that take place at the Observatorio Astronómico Los Molinos (from here on, OALM), located at the outskirts of Montevideo, Uruguay. Face-to-face activities, as well as social networks interactions (which have noticeably increased after 2020) are shown, as a way to take Astronomy and related sciences to as many people as possible.

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A didactic experience in the study of the proper motion of stars in the classroom

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The proper motion of stars is a very important topic in an Astronomy course. In principle, it allows us to measure the spatial speed of the stars in relation to the Sun and, from this, determine distances and other stellar parameters, allowing us to probe the proximities of the solar neighborhood and the speed of the local stars in the galaxy. That is why a work carried out by the Physics teachers in the subject of Astronomy II of the "Héctor Medici" Institute is presented. The work unifies a historical view of how and what was interpreted in the year 1718 when Edmund Halley found that the stars Sirius, Arthur and Aldebaran had moved in the sky more than half a degree since the observations made by Hipparcos, along with a didactic sequence. That is where students, through actions, link their knowledge and previous experiences, with some question that comes from reality and with information about an object of knowledge, managing to differentiate the improper movements of the stars, in which the coordinates stars are affected to the same extent by the movement of precession, nutation and aberration of light, deducing that only the proper movement corresponds to the real movement of the stars. One of the examples that has been highlighted in class is the proper motion of Barnard's Star moving 10.2"/year. One of the tools on which the work is based is the information from the Tycho catalog, as well as measurements made by Hipparcos and Gaia satellites.

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Citizen science on the fireball detection network: Bólidos del Cono Sur (BOCOSUR)

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We have successfully established a national fireball detection network, comprising 20 stations strategically positioned to cover the entire Uruguayan territory. The primary challenge we encounter is managing the substantial volume of generated data, leading us to initiate a crucial Citizen Science project. To widely disseminate the BOCOSUR Project, we crafted a website featuring comprehensive information and a fireball report form. Concurrently, we installed stations in high schools nationwide and conducted over 30 talks, engaging with a diverse audience of over 1000 students. Additionally, we conducted 4 virtual training workshops tailored for high-school teachers and students eager to contribute to video analysis within the network. Each workshop comprised 3 sessions. The initial meetings focused on presenting the project and delving into essential theoretical concepts, showing station operations, and imparting manual video classification skills. The third session aimed at applying acquired knowledge to video classification. Across these editions, we had 141 participants, including 105 students and 36 teachers from 40 different institutions. Around 70 participants successfully completed all activities. In the latest edition, over 1400 videos were analyzed, uncovering 170 meteors. Recently, we concluded the first phase of developing a web app for swift video classification. This was tested in a workshop with 30 teachers from diverse institutions, resulting in the classification of 70 as meteors, from a pool of almost 400 videos. Building a comprehensive database, not limited to fireballs, is crucial for training the machine learning classification algorithm developed by the AutoBol group as an Electrical Engineering final project (Ballestrino et al. 2022).

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AstroMicro: astronomy arrives in micro to television

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In the summer of 2023, the educational channel of the Chilean television channel TVN broadcasted the first six episodes of the show "AstroMicro". The event was a significant milestone for this interdisciplinary scientific communication project, bringing astronomers, animators, filmmakers, producers, writers, and project managers together. "AstroMicro", jointly funded by the TV channel, the Chilean Astronomy Society, and the Chilean Agency for Research and Development (Agencia Chilena de Investigación y Desarrollo), occurs on a "micro" where all the astronomical concepts are revisited with simple but accurate jargon relating the different experiences of the diverse passengers to everyday experiences in a bus. This approach avoids hierarchical communication within the team from the very early stages of the project, fostering communication and avoiding outsourcing the creative components of the product. In this talk, we will share details of the story behind the production, from the original idea to the screening of the first episodes.

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RECA: Promoting career development opportunities in astronomy to students of Colombian institutions

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The Network of Colombian Astronomy Students (RECA) is a student-led association formed in 2014. It seeks to support the astronomy student community with the aim of 1) Connecting the astronomical community with the main goal of supporting early career astronomers in Colombia, and 2) overcoming systematic barriers in academia and research. Early career and senior Colombian astronomers conform to this collaborative community. We will highlight the work from 3 nodes. The RECA education program works with schools from all regions of Colombia, providing tools and interaction with Colombian professional astronomers, using virtual chats, connection to remote observations in large telescopes, or personal counseling. The RECA mentoring program connects undergraduate students with astronomers in advanced career stages. They have personalized tutoring one-on-one, for career advice and guidance for applying to graduate programs in astronomy. Furthermore, the RECA summer internship program provides the opportunity for Colombian undergraduates to participate in astronomy research projects led by professional astronomers around the globe. All the programs are running their third version, and their successes have been seen with the positive impact of synergies within the Colombian student population of all academic levels. Funding for some programs has been obtained from national and international entities. The work of the RECA nodes highlights the importance of a student-led community both in connecting the astronomical community, and supporting beginning astronomers.

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The 0th Meridian of Buenos Aires

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The Buenos Aires meridian was used at the end of the 19th century as a reference origin to establish limits between the provinces and the then national territories. However, the exact position that materialized this meridian could never be established, with the consequent uncertainty in the limits that depended on it. In this work, we determine for the first time the exact position of the meridian of the city of Buenos Aires.

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Hands-on activities for studying light pollution: photometric measuring of zenith night sky brightness

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Night sky brightness (SB) is an important quantity to investigate light pollution contamination at a given site. It can be measured by different methods and apparatus, resulting in different forms of analysis and comprehension of the artificial light regime. The objective of this work is to present some of these measuring methods in order to elaborate hands-on scholar activities material. Two main methods were tested during the year of 2022 at the Observatório Abrahão de Moraes (Valinhos, SP, Brasil): by telescope with coupled CCD camera (the Argus telescope) and by IOS Dark Sky Meter (DSM) app.

Values for SB were found for the photometric Johnson B (16,82 ± 0,30 mag/arcsec^2) and V filters (16,49 ± 0,48 mag/arcsec^2), indicating that the sky at the observatory is highly light polluted, similar to big cities. The DSM app was consistent in its own scale to evaluate night sky brightness variations. However, it is roughly compatible with V or B bands from the UBV Johnson system, showing fainter magnitudes with 2,5 mag offset. The results were used to elaborate a script to conduct similar activities, both locally at a given observatory or remotely through the "Telescópios na Escola" project, allowing students to measure SB with the same Argus telescope used during the work. We also addressed experiments with the DSM app for light pollution teaching and outreach, in order to promote awareness and discussions about its impacts where the usage of astronomic apparatus is neither viable nor recommended.

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The scientific contributions of the first modern Colombian astronomer

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Astronomical interest within the current Colombian territory has its roots in the Botanical Expedition of the New Kingdom of Granada, which stimulated the creation of an astronomical observatory in 1803, the first one established in the New World to pursue systematic observations and meteorological studies. After the death in 1816 of its first director, Francisco José de Caldas, during the convulsive independence period, no major astronomical observations were made for decades, with few exceptions. In this work we delve into the contributions of the astronomer José María González Benito (JMGB), main reactivator of the National Astronomical Observatory of Colombia (OAN) in the second half of the 19th century, pointing out his pioneering efforts that put worldwide attention to it, and to his own private observatory. We have collected evidence supporting the fact that JMGB was one of the most important figures in the history of Colombian astronomy, not only due to the advances and discoveries that he achieved as a result of innumerable investigations and projects but also because of his unique sense of patriotism. As director of the OAN and of his private observatory (Flammarion Observatory), JMGB made numerous observations on different astronomical topics, being reports on comets among the most extended ones. In 1893 he observed the comet Rordame-Quénisset, nine days before the observations made from the US and France that were the ones designated as the official discovery. JMGB also observed meteor showers: the Leonids, on 14 Nov. 1867 and 13 Nov. 1899, and an unidentified one he reported on 24 Nov. 1872 in Andromeda. JMGB was a well-known astronomer in Europe and kept continuous communication with his colleague and friend Flammarion. Indeed, JMGB made observations from the Flammarion Observatory that had been completely unknown by the Colombian academic community until found by this research.

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Teaching astronomy basic concepts using smartphone sensors

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Smartphones are computers that, in addition to fitting in the palm of the hand, have the additional advantage of including several sensors that, with the appropriate knowledge, allow these devices to be transformed into very useful and economy portable laboratories for doing and teaching science.

In recent years, dozens of experiments have been proposed to teach science and to engage students by allowing them to do science on their own (Monteiro 2022), and in particular as valuable tools to teach astronomy (Monteiro 2020). Some activities can be carried out in basic courses of astronomy at high school and university. Using the smartphone's camera students can perform parallax stellar distance measurements on a scaled system to obtain the distance and the parallactic ellipse (Fitzgerald 2011). By using the light sensor of a smartphone, students are able to measure the light curve of a 3D printed scale asteroid to determine the period and shape factors (Ziffer 2019). Another useful activity with the same sensor aids to learn how to discover exoplanets by planetary transits in a scaled star system (Barrera-Garrido 2015).

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The Manuel Foster Observatory - History, science and new life of the first professional Observatory in Chile

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The history of the Manuel Foster Astronomical Observatory, affiliated with the Pontificia Universidad Católica de Chile and situated in the heart of Santiago's Metropolitan Park on top of San Cristóbal Hill, presents a prime opportunity to promote astronomy and natural sciences to the general public. Established in 1903, the observatory stands as one of the oldest in the Southern hemisphere. At the forefront of cutting-edge research in the early 20th century, it was designated a Historical Monument in 2010, and since then, it has garnered increasing attention from the public. Given the few million visitors and tourists who annually visit San Cristóbal Hill in Santiago, the Foster Observatory has undoubtedly become an essential stop on their journey. We highlight the scientific achievements, infrastructure and the recent transformation and repurposing of the Foster Observatory into an astronomical museum and outreach center. Our goal is to preserve and educate using its unique and original historical assets. We offer weekly diurnal and nocturnal observations that pave the way for a regular visitor program, primarily targeting students from educational institutions across the region, country and the continent.

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QUBIC Observatory: Education, Outreach and Culture connected with the origin of the Universe

B. García[1,2] and QUBIC Collaboration[2]

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The link of the human being with the cosmos is ancient. However, the approach to knowing what the universe is like has changed remarkably over time. New projects, with avant-garde instrumentation, are installed in astronomically exceptional regions, where the ancestral culture of native peoples has existed for centuries. Such is the case of QUBIC (Q-U Bolometric Interferometer for Cosmology), an instrument that aims to detect evidence of the time of universal inflation, installed in November 2022 in the Puna of Salta, land of the Kolla, Kolla del Desierto, Atacamas peoples, among others. At this crossroads between ancestral knowledge and modern science, QUBIC has developed, even before its realization, a link with the local inhabitants and seeks to establish a bridge between both cultures where, in addition, art has its space. In this presentation we seek to show a possible way to address the issues of education and dissemination of astronomy and astrophysics, living with them and transmiting their ideas to the world, maintaining the complex balance between these two cultures, to ensure that local communities take ownership of scientific developments that, without a doubt, contribute to the progress of not only of science, but also of the sites that host them and the local populations.

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Education and astronomical diffusion activities in Bolivia

Paola Ochoa[1]

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The activities of education and dissemination of astronomy in Bolivia, intend to reflect the work done with students, teachers, amateur astronomers, and the general public in the different regions of Bolivia, both in rural and urban areas. sharing the objectives of the IAU, with a public that for the most part is still unaware of this important institution. work that motivates us to continue growing.

[1]*NOC NAEC BOLIVIA International Astronomical Union.*

A Journey to the Moon: exploring multisensory resources in the teaching and learning of Astronomy

M. F. Gomes[1], A. C. Silva[2], P. A. Marques[2] and S. Lorenz-Martins[1]

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Astronomy education has the potential to inspire students to be engaged in STEM. However, to achieve this in the classroom is essential to promote equal access to information for everyone. Historically, Astronomy teaching uses mostly visual information as a resource. Given this, blind and visually impaired (BVI) students may encounter educational barriers in accessing information, as they need teaching materials adapted to their specific educational needs. Thus, the *Universo Acessível* project, located at the Valongo Observatory (UFRJ) in partnership with the Instituto Benjamin Constant, aims to develop didactic resources to improve the teaching and learning process of Astronomy for BVI students. The Brazilian Basic Education curriculum, focusing on Earth and the Universe, encourages students to reflect on the characteristics and position of celestial objects and the human species in the cosmos. Therefore, Astronomy Teaching plays a crucial role in students recognizing their position and role in the Universe. In this work, we present three multisensory resources for teaching about the Moon: tactile models, booklets, and a talking book. This initiative responds to challenges identified through qualitative research with Brazilian teachers, addressing difficulties in understanding astronomical concepts within the school curriculum. The Moon, along with related concepts, is a key component in most basic science education curricula. Each resource presents its specificity by engaging students through minds-on, hands-on and hearts-on interactions. The integration of multisensory resources fosters autonomy and inclusion. This approach contextualizes the learned content, instilling in teachers and encouraging critical thinking by highlighting historical and social backgrounds. It promotes interdisciplinary exploration and facilitates the exchange of personal experiences. Extending beyond people with disabilities, it reaches a diverse audience, ensuring proper usability and specificity for each resource.Active user participation is crucial to understand their real needs, overcome barriers, and seek new ways to make Astronomy accessible. In essence, these actions helps to make the Universe, everyone's home, accessible.

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Bridging Astronomical heritage and society in a science museum: Historical scientific instruments as a tool to preserve our history

M. F. Gomes[1], J. V. Fonseca[1] and D. F. Silva[1]

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Building bridges between society and historic scientific instruments (HSIs) in a museum collection is a challenging task, due to the different historical and sociocultural backgrounds involved in the construction of Brazilian society. Creating an environment that encourages dialogues about heritage and learning the history of national Astronomy through these artifacts requires the use of methodologies that foster the connection between the public and the objects. In this work, we aim to share some of the educational practices developed and applied using the astronomical artifacts from the collection of the Museum of Astronomy and Related Sciences (MAST), exploring not only their role in history or pedagogical dimensions but also their role in the process of constructing society, promoting dialogues and critical reflections on scientific culture.Through activities such as mediated guided visits, the project follows four main pillars: (1) models and modeling, (2) three-way interactivity (hands-on, minds-on, hearts-on), (3) museum education, and (4) horizontal teaching and learning. These aspects promoted the exploration of the HSIs from the collection that played an essential role in the development of Brazilian Astronomy, giving them a new meaning that transcends the walls of an exhibition. Using them as a powerful tool to bridge Astronomical heritage and society, it is possible to expand the socio-pedagogical dimension of the collection, promoting the process of identifying the public, since our memories, culture, and history as a society are also intangible heritage to be preserved.

[1]*Museu de Astronomia e Ciencias Afins.*

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Astronomy and sustainable cultural tourism. A proposal for the construction of the first cultural planetarium in Soacha-Colombia

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Commune VI of Soacha, Cundinamarca, faces challenges impacting its population. In areas like Altos de la Florida, existing tourist attractions could alleviate difficulties for residents, mainly families displaced by violence. The main community issues include limited formal education access, social stigmatization, and informal employment. Despite significant tourist potential in the municipality's hills, issues persist. There is a drive to promote a positive image through astronomical tourism, developing Soacha's first planetarium. This initiative aims to foster respect for nature and stars, promoting education and enhancing quality through astronomy programs. The planetarium, as the municipality's first, enriches infrastructure and provides community astronomy training. The primary goal is to educate the community, leveraging a nonprofit group's scientific outreach expertise. The planetarium complements this effort, promoting science in areas with rich indigenous traditions. Ultimately, this social integration for scientific knowledge appropriation could serve as an example for Latin American regions facing similar issues and undiscovered cultural richness.

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Asteroid District: Extending citizen science from Bogotá-Colombia

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Asteroid District is a citizen science program started by the District University for the promotion and appropriation of knowledge and scientific dissemination, focus its attention on the study of Near-Earth Asteroids (NEA). It's important to show the academic community the results of the training and projections carried out as a didactic strategy that develops complex thinking and the systemic vision of science, allowing conceptual approaches, it makes that the search for asteroids activity is constituted as a socio-scientific issue.

The Astronomical Observatory "LatitUD" of the Faculty of Engineering of District University has organized since 2021 Asteroid District, asteroid search campaigns framed in "The International Astronomical Search Collaboration (IASC)"; It has allowed more than 1200 people to participate to do researching and making discoveries from main belt asteroids and trans-Neptunian objects.

This research shows the activities carried out by project, their potential of these campaigns in the social appropriation of knowledge and scientic procedures, results, tensions and prospects, seeking to develop citizen science from astronomy, as an axis of construction of critical thinking, for making informed decisions, the development of scientific vocations and learning of the sciences. In this way, the importance of learning from non-formal educational settings and the inter-institutional collaboration becomes evident.

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Ethnoastronomy of the Curripaco, Piapoco, Puinave, Sikuani and Cubeo ethnic groups

G. M. Peña Idrobo[1] and A. M. Navarro Torres[1]

https://doi.org/10.22201/ia.14052059p.2026.60.43

In this collaborative research with students from a school in Colombia, we have explored and documented the rich tradition of indigenous astronomy from five ethnic groups: Curripaco, Piapoco, Puinave, Sikuani, and Cubeo. Our main objective was to rescue and preserve the unique astronomical knowledge of these communities, which has been transmitted through oral tradition and is at risk of being lost in the modern era. Throughout the process, we worked closely with respected members of each ethnic group, who shared with us their ancestral stories related to constellations and cosmos. Through extensive interviews and intercultural dialogues, identified the significant constellations for each ethnic group and documented the stories that accompany them. These stories not only hold astronomical value but are also intricately woven with beliefs, traditions, and ways of life of each community. Furthermore, we have created a unique star map that depicts the constellations of these ethnic groups, labeling individual stars with their scientific names and their corresponding names in indigenous languages. This map acts as a bridge between ancestral knowledge and contemporary science, enabling a deeper understanding the connections between both perspectives. One of the most striking findings of our research is how constellations are intricately linked with everyday practices, such as food agriculture. Each ethnic group has developed its own worldview that reflects its natural environment and its relationship with the land and the sky. Ultimately, our research not only highlights the importance of preserving these valuable traditions but also underscores the richness and diversity of human knowledge about the universe. By sharing these stories and insights with the global astronomy community at this international event, we hope to foster a greater appreciation for the connection between science culture, as well as inspire ongoing efforts to safeguard the voices and perspectives of indigenous communities in modern world.

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On the formation of NS-NS and NS-BH binaries from binary-driven hypernovae

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Keywords: *gamma-ray burst, stars: accretion discs, stars: Neutron, supernovae*

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The binary-driven hypernova (BdHN) model proposes an explanation for long gamma-ray bursts (GRBs) associated with type Ic supernovae (SNe). In this model, a binary system comprising a carbon-oxygen (CO) star and a neutron star (NS) companion undergoes various physical episodes, triggered by the core collapse of the CO star. This collapse leads to a SN explosion, forms a newborn NS (νNS) at its center and produces an accretion process on the νNS and the NS companion at super-Eddington rates. Using hydrodynamics simulations, we determine the maximum orbital period of the initial CO-NS binary that can stay bound after a BdHN event, resulting in NS-NS or NS-BH binaries. This provides insights into the outcomes of such cataclysmic events in binary systems.

We used the SN-SPH code (Fryer et al., 2006) to follow the evolution of the binary stars (the νNS and the NS companion) as the SN material expands. The simulations start when the SN shock front reaches the CO's outer radius. The νNS and NS, treated as point masses, interact gravitationally with SN ejecta particles and each other, while they can accrete additional particles from the SN ejecta (see Becerra et al. (2019) for more details of the simulations).

We perform simulations with a CO star coming from a progenitor with $M_{\rm zams} = 25M_\odot$ and a $2M_\odot$ and a $1.4M_\odot$ NS companion. At collapse , the CO star leaves a 1.85 $M_\odot$ νNS and ejects about 4.99 $M_\odot$ through the SN explosion. The code tracks the position and velocity evolution of all the SN ejecta particles as well as the point-mass particles. In order to determine whether the system remains gravitationally bounded, we compute the total energy of the νNS-NS system as:

$$E = \frac{1}{2}\frac{M_{\nu\rm ns}M_{\rm ns}}{M_{\nu\rm ns}+M_{\rm ns}}|\vec{v}_{\nu\rm ns}-\vec{v}_{\rm ns}|^2 - \frac{GM_{\nu\rm ns}M_{\rm ns}}{|\vec{r}_{\nu\rm ns}-\vec{r}_{\rm ns}|}\,, \quad (1)$$

where $(M_{\nu\rm ns}, \vec{r}_{\nu\rm ns}, \vec{v}_{\nu\rm ns})$ and $(M_{\rm ns}, \vec{r}_{\rm ns}, \vec{v}_{\rm ns})$ are the mass, vector position and velocity of the νNS and the NS companion, respectively. If the total binary energy becomes negative, $E < 0$, the remnant systems of a BdHNe event remain gravitationally bounded. Then, the CO-NS initial systems with the longest initial binary period, $P_{\rm orb,max}$, is the one that makes $E = 0.0$. Figure 1 shows the relation between $P_{\rm orb,max}$ and the SN energy, $E_{\rm sn}$. There is a maximum SN energy that will lead to bounded systems, otherwise, all binary systems will remain unbounded regardless of the initial binary period. The minimum SN energy is about 5.97×10^{50} ergs and 6.64×10^{50} ergs for the 1.4 $M_\odot$ and 2 $M_\odot$ NS companion, respectively.

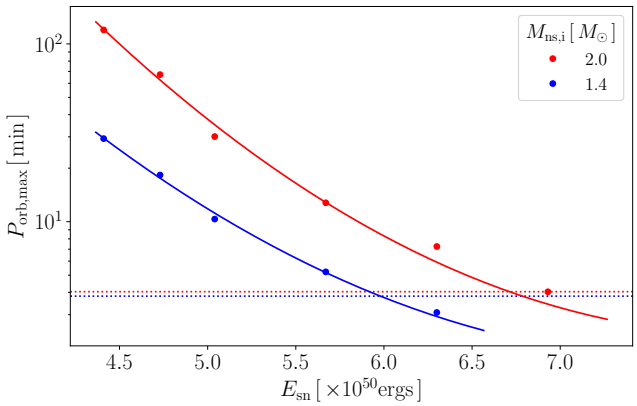

Figure 1. Longest initial binary period for which the outcome binary after a BdHne event remains bounded in function of the SN energy. The horizontal dotted lines represent the minimum period for the system, defined as the minimum binary separation at which there is no Roche-Lobe overflow before the SN explosion.

The final bounded systems will be compact binary systems (NS-NS or NS-BH), which will eventually merge through the emission of gravitational in 10^4 to 10^9 yrs. BdHNe I produces a series of rapidly merging NS-BH binaries that give rise to ultrashort gamma-ray flashes (U-GRFs) (Fryer et al., 2015).

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Binary synthesis of merging compact object populations from evolving initial conditions

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Keywords: *gravitational waves, stars: binaries: close binaries, stars: black holes, stars: neutron*

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In this work, we implement models for a metallicity- and SFR-dependent IMF and correlated initial mass ratio, orbital period and eccentricity in performing binary population synthesis with the code `COMPAS` for binaries born at redshifts up to 10. We are able to obtain the time-evolution of all three classes of compact binary mergers, which we find found to peak between redshift 1 and 4 depending on the model; additionally, we found a robust trend of merging black holes to be more massive at higher redshift.

We have studied two variations of initial condition models in performing binary population synthesis (BPS) with the code `COMPAS`. In the "Canonical" model, when sampling our newborn binaries for evolution, we implement the invariant Kroupa (2001) IMF, for sampling masses, and the traditional independent distributions for orbital parameters: uniform for the mass ratio (q), log-uniform for the orbital period (P), and set $e = 0$. In the "IGIMF" model, we implement the varying IMF by Jeřábková et al. (2018), based on empirical fits that make it top-heavy at low metallicities and high SFRs, alongside the correlated orbital parameteres by Moe & Di Stefano (2017).

Based on the work of Chruślińska et al. (2020) (and references therein), we sample metallicity-SFR (or redshift) pairs based on the cosmic star formation history in order to build a composite binary population with binaries born between redshift 0 and 10. For each of our two initial models, we sample and evolve $\sim 10^8$ binaries over 120 different metallicity-SFR/redshift pairs.

Our main results are the time-evolution of the merger rates up to redshift 10 for black hole-black hole (BHBH), black hole-neutron star (BHNS) and neutron star-neutron star (NSNS) mergers. Two differences between the results for the IGIMF model and for the Canonical model stand out: the later positions for the merger rate peaks; and rates one order of magnitude greater for BHBH and BHNS mergers. Both are a consequence of implementing a IMF that becomes top-heavy for high SFRs. Because the SFR peaks around $z = 2$, the rate peaks come at later redshift; and because a top-heavy IMF increases the production of black hole merges more strongly than that of neutron star mergers, the BHBH and BHNS rates are more affected. We also find a trend of black hole masses to increase with redshift, particularly strong in the IGIMF model.

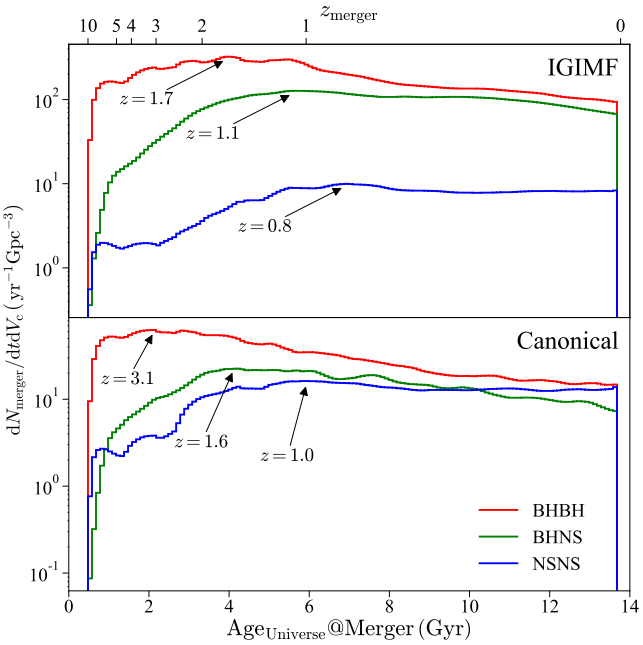

Figure 1. Merger rate time-evolution for BHBH, BHNS and NSNS mergers in both IGIMF and Canonical models.

A complete exposition and discussion of results for rates and masses of all three merger classes, in both IGIMF and Canonical models, will be published in the near future as de Sá et al. (submitted).

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Machine Learning explorations in GRB Studies: from classification to extended emission identification

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Keywords: *gamma-ray bursts, high energy astrophysics, stars: mass loss, stars: pre-main sequence*

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Gamma-ray bursts (GRBs) have traditionally been classified based on their duration. Nevertheless, extended emission (EE) GRBs, characterised by a duration larger than two seconds and properties similar to short GRBs, challenges the conventional classification methods. By using a non-supervised machine-learning technique (t-distributed stochastic neighbor embedding, t-SNE),we performed a better phhotometric classification and the identification of extended emission in Swift/BAT GRBs. Furthermore, we introduce an innovative tool, `ClassiPyGRB`, designed for astronomers whose research centers on GRBs from Swift/BAT telescope.

Gamma-ray bursts (GRBs) have been classified mainly considering their duration (Kouveliotou et al., 1993). Short GRBs (SGRBs) typically last less than than two seconds, exhibit harder spectral properties, and are associated with the merging of compact objects, such as neutron stars or a neutron star and a black hole (i.e., Berger, 2014). On the other hand, long GRBs (LGRBs) have a duration larger than two seconds, a softer emission, and are associated with the collapse of massive stars (i.e., Bromberg et al., 2012).

EEGRBs challenge this classification scheme by having a total duration larger than 2 seconds but sharing characteristics of both SGRBs and LGRBs (i.e., Gehrels et al., 2006). Finally, duration classification also has instrumental selection effects, as demonstrated by Qin et al. (2013). This evidence remarks the need for a more comprehensive understanding of GRBs and motivates further exploration into alternative classification criteria.

Jespersen et al. (2020) proposed a new classification scheme based on similarity analysis via t-SNE, a popular machine learning (ML) algorithm. Although its classification discerns two subgroups of GRBs, they do not consider the impact of noise in their classification, and their dataset is currently outdated.

In García-Cifuentes et al. (2023), we use a dataset consisting of BAT GRBs observed until July 2022 by the Swift/Burst Alert Telescope instrument in all its energy bands. We reduced noise on the light curves using the Bayesian approach `FABADA` (Sánchez-Alarcón & Ascasibar, 2023). Subsequently, we preprocessed the noise-reduced light curves using the same procedure as Jespersen et al. (2020), and we applied t-SNE implemented on `scikit-learn` in *Python3*.

One of the most relevant results obtained in our research is that it is possible to discern two subgroups of GRBs in the t-SNE maps, and their properties are similar to those related to SGRBs and LGRBs. Moreover, our research highlights the relevance of handling noise in ML-based classifications, and we show that the dependence on duration remains invariant despite reducing noise.

On the other hand, it is possible to discern small clusters of EEGRBs in the reduced-noise classification. The most significant outcome of our research is that, by examining the nearest neighbors of previously identified EEGRBs, we can effectively classify new instances of EEGRBs. This approach not only streamlines the analytical effort but also introduces a novel method for classifying such events.

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First results of the glitching pulsars monitoring program at the Argentine Institute of Radioastronomy

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Although pulsars exhibit a particularly stable rotation, this stability can be affected by glitches. This phenomenon consists of a sudden increase in the rotation frequency of pulsars. Its cause is not well understood, but it is likely related to the behavior of matter inside neutron stars. Therefore, glitches can provide constraints on the equation of state of neutron stars. With the aim of thoroughly characterizing these glitches, since 2019 we have been conducting a high-cadence monitoring campaign of glitching pulsars from the Argentine Institute of Radio astronomy (IAR). Up to date, we have detected and characterized two giant glitches in the Vela pulsar, one in PSR J0742−2822, one in PSR J1740−3015, and two mini glitches in PSR J1048−5832. We fully describe them in this poster presentation.

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Stellar winds in the galactic centre: Variable accretion and formation of a disc

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Sgr A*, located only 8 kpc away, allows us to study in detail the accretion process on to a supermassive black hole. Only in our Galactic centre we can directly observe the source of the material feeding the accretion, which in this case corresponds to around 25 young, massive stars, with powerful stellar winds. We describe our hydrodynamical models of the gas surrounding Sgr A*, originating from the observed stars, with known orbits and stellar wind properties. Our simulations show that these winds and their collisions can naturally account for the properties of the hot plasma detected in X-ray observations. Moreover, the complex interaction of the winds with the medium produces cold clumps and streams, and perhaps even a disc around the black hole, as inferred from ALMA observations. Finally, the stellar orbits and the infall of streams make the accretion vary on time-scales of decades to millennia, potentially explaining the observed X-ray echoes related to past activity from Sgr A*.

For more details please see https://doi.org/10.3847/2041-8213/ab5e81.

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The length of the slow stable hybrid star branch and its linkage with neutron star observations

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The internal composition of neutron stars, one of the densest astronomical objects in the universe, is still unknown. Although in the last decade, with the onset of multi-messenger gravitational wave astronomy, several astrophysical observations placed strong constraints on these compact objects, there is still a lack of understanding of the dense matter equation of state. In this work, we model neutron stars as hybrid stars -composed of an inner core of quark matter and a mantle of hadronic matter-, considering an abrupt and slow first-order hadron-quark phase transition in their core. We model the hadronic phase with a piecewise polytropic fit, and the inner quark core through a Color Flavor Locked superconducting equation of state, with corrections due to the strong coupling constant, within the framework of the MIT Bag model. In the framework of this abrupt and slow scenario, it is possible to obtain an extended branch of stable stellar configurations. It has been shown that the appearance of such branches could resolve the existing tension between current astrophysical observations. We analyze the behavior of this extended stability branch by quantifying and systematically studying, for the first time, its length, relating this quantity to fundamental properties of the hybrid equation of state. This study allows not only a deeper understanding of the extended stability scenario with slow hadron-quark conversions but could help reveal the mystery of the composition of neutron stars and, consequently, clarify the uncertainty about the equation of state of dense matter.

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wI asteroseismology revisited: universal relationships that include slow stable hybrid stars

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We show that, within the slow hadron-quark conversion regime where extended branches of hybrid stars (SSHS) appear, all universal relationships for wI-modes available in the literature do not hold (for details, see Ranea-Sandoval et al. 2022). Then, we show newly discovered universal relationships that include SSHS, and present potential astronomical applications of such relationships, showing that, if the frequency and damping time of the fundamental mode are measured, its mass, radius, and dimensionless tidal deformability can be inferred (for details, see Ranea-Sandoval et al. 2023). The errors of such estimates are smaller than a few per cent for the mass and the radius. For the dimensionless tidal deformability, the errors for compact objects with masses above 1.4 solar masses are typically less than 100%.

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Impact of the matching formalism in neutron stars and their oscillation modes

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The interior of neutron stars (NS) contains matter with densities several times higher than nuclear atomic density. Obtaining an accurate equation of state (EoS) to describe NS is crucial for enhancing our understanding of matter in such extreme environments. To achieve this, we built ten EoS by considering three diferent crusts which are added to the core of these compact objects using a new thermodynamically consistent formalism. Essentially, for an isolated and cold NS, we assume a linear relationship for pressure and energy density in a small region between the core and the crust. This establishes an interpolation function in the pressure/baryonic-chemical-potential plane. We compared this new way of "gluing" EoS with the classical method that neglects causal and thermodynamic consistency. Then, we solved the TOV equations, which describe a non-rotating, spherically symetric and static object, to obtain the mass-radius relationship and compared it with the existing observational constraints of NS. In addition, we explored changes that the new matching formalism can cause in the oscillation modes. With alternative matching formalisms, even for two or three interpolations of the same crust, the p_1 mode exhibited differences in oscillation frequencies and damping times for low-mass NS. In contrast, no visible effects can be appreciated for the f mode, neither in the three models of the crust nor in the interpolations considered. We conclude that independently of the model used for the EoS, the method of construction will impact in NS observables such as the radius, frequencies and damping times of non-radial oscillations.

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A review of the current state of research on extragalactic sources that emit gamma rays in the TeV range, using the Cherenkov technique

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Gamma rays are a form of high-energy electromagnetic radiation that is unaffected by galactic magnetic fields. Although the study and detection of gamma-ray emissions, both from satellites and terrestrial sources, have experienced significant advances throughout history, starting with the installation of the MIT gamma-ray instrument in the 1960s, we will focus on the sensitivity of the Cherenkov atmospheric technique. Extensive air showers result from collisions between photons and protons. The total cross-section of these collisions has measured center-of-mass energies up to 200 GeV. The predominant interactions are electromagnetic, with cross-sections for the production of hadron and muon pairs much smaller than those for electron pairs. In this electromagnetic cascade, photons generate electron-positron pairs, and electrons and positrons generate photons through bremsstrahlung, exponentially increasing as it propagates through the atmosphere, dividing the primary energy among more and more particles. However, as the energy decreases, the ionization energy loss mechanism becomes more important than bremsstrahlung.

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Particle acceleration in the heliosphere and in supernova remnants

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Cosmic rays are charged particles that permeate astrophysical environments with energies much higher than the ambient thermal particles. The bulk of the galactic cosmic-ray protons and heavier nucleus, with energies up to PeV, are most probably energized in shocks resulting from supernova remnants (SNR) expansion in the interstellar medium, although the process is not yet fully understood. In the interplanetary medium, directly detected ions with energies in the tens of MeV range are correlated with shock fronts. This research aims to develop a one-dimensional model to study the confinement and injection of energized protons in the heliosphere, using magnetohydrodynamic (MHD) simulations, that can be compared with direct particle observations and also with previous models. Furthermore, this modified model, including a kinetic representation of the relativistic particles (Particle-In-Cell-MHD), was applied in SNR scenarios. Our models were able to reproduce the evolution of shock events observed in the heliosphere, in accordance with previous MHD models in the literature, with the advantage of providing the energy distribution of the energetic particles, which can be used to better constrain the acceleration and diffusion processes. In the SNR case, our simulations produced the instabilities believed to regulate the self-confinement of the particles which affect the acceleration efficiency. In the future, we intend to apply it to construct non-thermal emission models of SNR that can be compared to observations. This approach will contribute to the understanding of the cosmic ray acceleration process, as certain open questions, such as the development of instabilities near the shock, can be tested in the interplanetary medium, where direct observations are available.

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Breaking of quadrupolar f-modes universal relationships under the slow hadron-quark conversion regime

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In the past fifteen years, our understanding of compact stars has significantly advanced through key observations, such as the pulsars PSR J0348+0432 and PSR J0740+6620, whose radius has recently been estimated using NICER and XMM-Newton data, along with the analysis of gravitational waves (GW) events, as GW170817.

In this work, we consider polar perturbations, and we calculate the frequency and damping time of the quadrupolar fundamental f-mode of compact objects, constructed using a wide range of model independent hybrid equations of state that include quark matter. We give special attention to the impact of the hadron-quark conversion speed that, in the slow case, gives rise to a branch of slow stable hybrid stars. Moreover, we study the validity of universal relationships proposed in the literature and find out that none of them remains valid when slow stable hybrid stars are taken into account, as has also been shown for the wI-modes and f-modes in RaneaSandoval:2022bou, PhysRevD.107.123028 respectively. This fact could constrain the applicability of asteroseismology methods with fundamental modes designed to estimate the properties of pulsating compact objects. We hope that this result could be tested with the start up of the third generation gravitational wave observatories, which might shed some light on the f-mode emission from compact objects.

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The dark sector window with extreme laser pulses

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Parameter bounds for the dark matter candidates can be obtained not only from astrophysical sources or large particle colliders but also from laser experiments. One of these experiments consists of shining a wall with a laser and trying to convert the photon into a dark matter candidate particle through an external magnetic field coupling, named light shining through the wall (LSW). On the other side of the wall, another magnetic field region would reconvert the weak interacting particle into a photon before passing through a detector. We explore the possibility of implementing LSW to detect dark matter candidates, taking advantage of the power laser pulses achieved at the Extreme Light Infrastructure and the Shanghai Superintense Ultrafast Laser Facility shortly.

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A review on the post-merger gravitational waves emitted in binary neutron star mergers

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Gravitational waves detected from the inspiral stage of a binary neutron star merger give information about the nature of the initial components such as their masses, spins, radii and tidal deformabilities. Similarly, observations of the post-merger stage would give hints on the characteristics and the evolution of the remnant of these coalescences. Since post-merger observations by earth-based detectors are not available yet, only numerical simulations are used to study this stage. Therefore, we will review the main characteristics of this kind of mergers, as well as the results given by the numerical simulations in order to better understand the different outcomes that are produced in these systems and how the final fate is related to the initial components.

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The role of modeling and observations for a complete explanation of coronal heating (Invited contribution)

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Keywords: *activity, corona, magnetic fields, sun: atmosphere*

Abstract

The problem of how the solar corona is hundreds of times hotter than the underlying photosphere continues to be a subject of intense study and interest for the solar physics community. One of the main persisting challenges is that fundamental processes occur on spatial scales that are beyond the resolution power of instruments presently available. Therefore, a strong interaction between models and observations is necessary. From the side of modeling, the highly diverse spatial scales, from single particle gyroradii (cm to tens of m) to the structure of coronal magnetic loops (tens to hundreds of Mm), make it impossible to include all of them in single numerical simulations, demanding instead the use of different approaches and physical formalisms for different spatial scale regimes. Regarding observations, it is necessary to put under the same phenomenological frame diverse sets of data obtained in wavelengths spanning from radio to X-rays. Here, we review the main aspects of the problem, its present state and some of the recent advances in understanding the underlying processes.

Resumen

El problema de cómo la corona solar se encuentra cientos de veces más caliente que la fotósfera subyacente continúa siendo objeto de intenso estudio e interés para la comunidad de física solar. Uno de los desafíos que aún persisten es que los procesos fundamentales ocurren en escalas espaciales que están más allá del poder de resolución de los instrumentos actuales. Por lo tanto, una fuerte interacción entre modelos y observaciones es necesaria. Por parte de los modelos, la diversidad de escalas espaciales, desde el radio de giro de las partículas individuales (de cm a decenas de m) a la estructura de los arcos magnéticos coronales (decenas a centenas de Mm), hace imposible incluir todas ellas en un mismo escenario numérico, demandando en su lugar diferentes aproximaciones y formalismos físicos para regímenes en distintas escalas. Respecto de las observaciones, es necesario poner bajo un mismo marco fenomenológico diversos conjuntos de datos obtenidos en longitudes de onda desde radio hasta rayos X. Aquí repasaremos los aspectos principales del problema, su estado presente y algunos de los avances recientes en la comprensión de los procesos fundamentales.

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1. Introduction

In the second half of the nineteenth century, when astronomers began to use spectrographs to observe the solar corona during total solar eclipses, they found spectral emission lines associated to known elements such as H and Ca, but they also found previously unidentified lines that they associated to unknown elements, such as He, found on Earth in the first decade of the twentiest century, and a suspected new element called "Coronium". It wasn't until the 1940s that it was found that the "Coronium" line corresponded in fact to Fe in a high state of ionization (FeXIV, Edlén, 1943), indicating that the solar corona must be at a temperature of more than 1 MK. Thanks to radiative transfer modeling and observations, nowadays we count with a reconstruction of the coronal thermal structure consisting of a photosphere (the main radiant surface of the Sun, whose spectrum is mostly in the visible range) at 5800 K, a chromosphere extending up to 5 Mm with temperatures ranging from 4500 to 20000 K, and a narrow transition region (TR) of a few hundred km width where

temperatures vary from a few tens of thousands of K to more than 1 MK in the solar corona (Foukal, 2004). The density suffers similarly dramatic changes from 10^{17} cm^{-3} in the photosphere to 10^{12} cm^{-3} in the chromosphere to 10^{9} cm^{-3} in the corona. It was shown that the energy fluxes needed to keep the corona at those temperatures are of the order of 10^{7} erg cm^{-2} s^{-1} on active regions and 3×10^{5} erg cm^{-2} s^{-1} in the quiet-Sun (Withbroe & Noyes, 1977). It has been demonstrated that the only way to store and release those amounts of energy in the solar corona is by means of the magnetic field. The Poynting flux injected by convective motions, acting on magnetic field lines rooted on the photosphere, provides the required energy budget (Priest, 2014).

The solar atmosphere is strongly dominated and structured by the magnetic field. Due to the low magnetic resistivity, leading to the "frozen-in" condition of the plasma and the magnetic field, and the force free condition due to the low plasma β (the ratio between the gas and magnetic pressures) in the low corona, both heat conduction and plasma motions are confined along magnetic field lines (Reale, 2014). For this reason, the coronal plasma, particularly in active regions, is observed to be structured in the form of magnetic flux tubes or loops. These can be considered the building blocks of the coronal structure. Any model proposed to explain coronal heating must be consistent with the observed characteristics and evolution of these loops (Klimchuk, 2015).

The physical mechanism by which free magnetic energy accumulated in the field is released in the form of plasma heating, is still the subject of intense study and discussion. The proposed processes can be broadly divided in three main families: 1) the release of magnetic stress by reconnection (see, e.g., Parker, 1988; Priest, 2011; López Fuentes & Klimchuk, 2010) or Ohmic dissipation (Gudiksen & Nordlund, 2005), 2) magnetohydrodynamic waves dissipation by resonant absorption (O'Neill & Li, 2005) or phase mixing (Heyvaerts & Priest, 1983), and 3) turbulent regimes (Dmitruk & Gómez, 1997). As we thoroughly describe in the following sections, in this report we focus on results obtained with the first type of models, in particular, the so called nanoflare heating model, originally proposed by Parker (1988).

2. Loop Modeling and Observations

In order to test the predictions of the models described in Section 1, it is necessary to convert the heating rates provided by them in emission outputs susceptible to be compared with observations. To do this, it is first necessary to compute the response of the plasma to the heating, in terms of the evolution of its temperature, density and velocity. As we described in Section 1, the coronal plasma, particularly in active regions and in the low corona in general, is structured in the direction of the magnetic field, forming coronal loops. It is therefore possible to model the evolution of the plasma in the loops using a one-dimensional hydrodynamic approach. This consists in solving the equations of mass, moment and energy conservation, plus an equation of state (see e. g., Reale, 2014), to obtain the temporal evolution of the spatial distribution of temperature, density and velocity of the plasma along the loops. The hydrodynamic modeling output can be further modeled to simulate synthetic observations to be eventually compared with actual observations. Alternatively, diagnostic techniques can be applied directly to observations to infer temperatures, densities and velocities that can be compared with hydrodynamic modeling outputs.

Among the usual procedures to obtain temperatures and densities from observations, one of the simplest is the so-called filter ratio technique. Considering the emission in two different instrumental bands, in the isothermal case it can be shown that the ratio of the intensities is a function only of temperature. The temperature can then be obtained from the instrumental response in both bands, $I_a/I_b = S_a(T)/S_b(T) = R(T)$, and the density is obtained from the emission measure in any of those bands (see, e. g., López Fuentes, M. C. et al., 2007). A more sophisticated procedure, useful to characterize multithermal plasmas, is to obtain the differential emission measure distribution, DEM. Expressing the emitted intensity as an integral in temperature (instead of as a spatial integral), $I = \int DEM(T)\, S(T) dT$, the method consists in testing different parametrizations of the DEM, choosing the one that better fits simultaneous observations in different bands or spectral lines (see e. g., Schmelz & Pathak, 2012; Warren et al., 2012; Nuevo et al., 2020).

3. Heating Regimes

According to the wavelength in which they are observed, coronal loops can be classified in two broad classes: 1) hot loops, mostly observed in soft X-rays in active region cores, with temperatures above 2 MK and densities of the order of 10^{8} cm^{-3}, and 2) "warm" loops, observed in the Extreme Ultraviolet (EUV) in the periphery of active regions, with temperatures of around 1.5 MK and densities of more than 10^{9} cm^{-3}. One of the first studies dedicated to characterize the thermal state of loops was done by Rosner et al. (1978). They assumed that loops were in a state of equilibrium, or evolving in quasi-static equilibrium, such that a slowly varying heating source was instantaneously balanced by thermal conductive and radiative losses. Later research showed that although hot loops observed with the Soft X-ray Telescope (SXT, Tsuneta et al., 1991) on board Hinode, were consistent with this kind of scenario (Porter & Klimchuk, 1995), warm loops observed with the Transition Region and Coronal Explorer (TRACE, Handy et al., 1999) had densities and scale heights that were too high to be consistent with equilibrium solutions (Aschwanden et al., 2001; Winebarger et al., 2003). Instead, it was demonstrated that the high densities and broad temperature distributions observed in warm loops could

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only be explained by impulsive heating (see, e. g., Warren et al., 2002).

In a recent paper, Nuevo et al. (2020) studied 13 loops of the warm class observed with Atmospheric Imaging Assembly (AIA, Lemen et al., 2012) on board the Solar Dynamics Observatory. They modeled the analyzed loops using two alternative scenarios: 1) constant heating assuming loops in equilibrium, and 2) heating by impulsive events or nanoflares. Their results showed that the loops were overdense with respect to loops in quasi-static equilibrium and that impulsive heating correctly reproduced the observed densities and temperatures. They also found that the width of the temperature distribution was consistent with loops formed by multiple strands.

4. Nanoflare Model

Proposed by Parker (1988), the nanoflare model is based on the idea that loops are made of elementary subresolution magnetic strands that are shuffled and tangled by photospheric convective motions. This, in turn, produces field discontinuities and current sheets leading to reconnection heating events called nanoflares. The evolution of observed loops would be, then, due the summed contribution of a number of these strands evolving independently. López Fuentes & Klimchuk (2015) developed a model based on the interaction and reconnection between strands using a cellular automata scheme. The evolution of the plasma on each indifvidual strand was modeled using the Enthalpy Based Thermal Evolution of Loops (EBTEL, Cargill et al., 2012) code. In a later work (López Fuentes & Klimchuk, 2016) they showed that synthetic lightcurves constructed by adding the contribution of the evolution of a number of strands from the model, using typical solar parameters, reproduced the main statistical properties, such as the mean, standard deviation and skewness, of real observed lightcurves. They also showed that the model reproduced DEM distributions consistent with other authors observations (Schmelz & Pathak, 2012; Warren et al., 2012). Analyzing cross correlation factors between the emission in different SDO/AIA bands, Viall & Klimchuk (2012) found time lags that are consistent with the presence of impulsive heating and cooling processes, confirming the plausibility of the nanoflare model.

5. Plasma Flows

An important prediction of the nanoflare model is the ubiquitous presence of plasma flows. Doppler shifts and non-thermal broadenings of spectral emission lines associated with upflows and downflows are frequently observed in coronal observations (Tripathi et al., 2012; Winebarger et al., 2013). The density changes associated with the nanoflare model are accompanied by flows from and into the chromosphere and corona. López Fuentes & Klimchuk (2022) analyzed the effect of plasma flows from the nanoflare model on EUV synthetic spectral lines. The lines were obtained integrating the contribution of model strands along typical observation times. They considered a set of 11 lines of ions with temperature formations ranging from 0.5 to 7.8 MK. Lines were integrated along 30 s samplings, as it is customary for spectrometers like the EUV Imaging Spectromenter (EIS) on board Hinode, taken from the modeled strand evolutions. The obtained synthetic lines were then analyzed with usual diagnostic techniques based in the computation of the moments of the line profiles, that provide Doppler shifts and non-thermal widths. The results are generally consistent with observations for the temperature range below 3 MK (Brooks & Warren, 2016; Testa et al., 2016). For the hotter temperature range (above 5 MK) there are still very few observational reports to compare with. This is the kind of observations expected from a new generation of instruments dedicated to explore that temperature range in the near future (see, e. g., De Pontieu et al., 2022).

6. Quiet-Sun Loops

In the quiet-Sun corona, loops are usually not directly observable as they are in active regions, mainly because the contrast with their environment is very low. Using the DEM tomographic technique described by Vásquez (2016), Mac Cormack et al. (2017) reconstructed the mean coronal plasma properties along a solar rotation. The technique provides the 3D distribution of the mean temperature and density in a spherical grid between 1.025 and 1.25 $R_{\odot}$. Combining the obtained distributions with potential models of the coronal magnetic field (PFSS) they reconstructed and characterized physical parameters along integrated loops. Mac Cormack et al. (2023, in preparation) used the tomographic reconstruction of Carrington rotation 2082 (April 2009) to statistically analyze mean thermal properties of reconstructed loops. Using a superposed epoch analysis procedure they compared these reconstructions with loops modeled with a 1D hydrodynamic code (HYDRAD, Bradshaw & Cargill, 2013) for constant and impulsive heating. Their results showed a good consistence with impulsive heating localized near the base of the loops.

7. Conclusions

We analyzed some of the problems and methods associated with the study of coronal heating. We saw that due to the fact that most fundamental mechanisms lie beyond present instrumental capabilities, the interaction between models and observations is crucial for a complete explanation of the problem. We introduced the nanoflare model and we showed that it is able to explain much of the sometimes confusing observational evidence, making it one of the main candidates to explain coronal heating (at least in active regions and the lower corona). The investigations reported here suggest that the statistical characteristics

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of quiet-Sun loops may be also consistent with impulsive heating. Among things that still need to be confirmed is the presence of high velocity upflows at temperatures above 5 MK. It is expected that new space and ground observatories (Parker Solar Probe, Solar Orbiter, MUSE, Solar-C, DKIST) and novel methods of analysis would soon provide long awaited answers and newer questions for future study.

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CME deflections: A brief review and new insights (Invited contribution)

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Keywords: *coronal mass ejections, magnetic fields, Sun*

Abstract

Recent research has demonstrated the significant role played by magnetic structures surrounding coronal mass ejection (CME) events in their initial development and progression. Coronal holes and pseudostreamers are key components of the corona that contribute to the deviation of CME trajectories from their radial path. Therefore, comprehensive observational studies, coupled with theoretical interpretations and numerical simulations, are vital in understanding the early evolution of CMEs and accurately determining their three-dimensional trajectory in the interplanetary medium. This approach is crucial for reducing errors in estimating the arrival time of geoeffective events. In this concise review, it is compiled from the theoretical, numerical, and observational investigations that have provided insights into the factors influencing CME deflection away from their typical radial trajectory.

Resumen

Investigaciones recientes han demostrado el importante papel que desempeñan las estructuras magnéticas que circundan los eventos de eyecciones coronales de masa (ECM) en su desarrollo inicial y progresión. Los agujeros coronales y los *pseudostreamers* son componentes clave de la corona que contribuyen a la desviación de las trayectorias de las ECM de su trayectoria radial. Por lo tanto, estudios observacionales exhaustivos, junto con interpretaciones teóricas y simulaciones numéricas, son vitales para comprender la evolución temprana de las ECM y determinar con precisión su trayectoria tridimensional en el medio interplanetario. Este enfoque es crucial para reducir errores en la estimación del tiempo de llegada de eventos geoeficaces. En esta concisa revisión, se recopila las investigaciones teóricas, numéricas y observacionales que han proporcionado información sobre los factores que influyen en la deflexión de las ECM fuera de su típica trayectoria radial.

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1. General

The understanding of coronal mass ejections (CMEs) propagation is critical for space weather forecasting, with factors such as deflection of CME playing significant roles.

Observational research has revealed interesting patterns regarding CME deflection. During periods of minimal solar activity, CMEs consistently deflect toward lower latitudes, where the heliospheric current sheet -a region of minimal magnetic energy- is located (Cremades & Bothmer, 2004). However, in high-activity periods, this trend is lost.

Considering other structures with regions of low magnetic energy -as pseudostreamers (PSs)- suggests that the magnetic environment surrounding the eruption region can influence the deflection of CMEs within the first few solar radii (Liewer et al., 2015). Analyzing the magnetic forces generated by the background corona, Shen et al. (2011) show the magnetic pressure play pivotal rol.

On the other hand, certain magnetic structures, like coronal holes (CHs) and active regions (ARs), possess the ability to repel CMEs. This deviation occurs due to the strong magnetic field topology of the AR and the open flow area of an adjacent CH (Möstl et al., 2015).

However, there are observational studies that show that it is difficult to predict the trajectory of a CME when there are multiple magnetic structures surrounding the source of the CME (Jiang et al., 2007; Sieyra et al., 2020).

Therefore, in order to characterize general behaviors, it is essential to comprehend the root causes of deviations. Given the intricacies of the phenomena, it is necessary to

consider various factors and mechanisms that contribute to these deflections.

2. Repulsors and Attractors

Observational studies have examined how CHs deflect CMEs from their radial trajectory. Cremades et al. (2006), analyzing a large number of events, showed that CMEs systematically move away from CHs. From their analysis, they demonstrated the existence of a force that causes this divergence, which is linearly dependent on the area of the CH and inversely proportional to the distance between the CME source and the hole. Three years later, Gopalswamy et al. (2009), additionally showed that this force is linearly dependent on the magnetic field of the CH. In this way, CHs are considered as magnetic walls, acting as repulsors that push CMEs away.

On the other hand, pseudostreamers act as attractors of CMEs. Yang et al. (2015) show in observational studies that the CME approaches the region of low magnetic energy, and an imbalance in magnetic pressure occurs due to magnetic reconnection, deflecting the CME.

3. Model and Numerical Studies

Observations in white light reveal that CMEs are composed of a leading edge, a dark cavity, and a bright core. This structure corresponds to a flux rope (FR) model, where a helical magnetic field can support and expel material from the corona into the interplanetary medium through coronal mass ejection. Using the catastrophe model proposed by Forbes (1990), the dynamics of this FR can be resolved by solving the MHD equations through numerical simulations.

In this way, in Sahade et al. (2020); Sahade et al. (2021), the deflection of a FR in the presence of a CH was analyzed in isolation. We found that the combination of both magnetic structures creates a region of minimum magnetic energy where the CME is deflected, and then the deflection is channeled by the magnetic field lines of the CH. We numerically demonstrated that the deflection increases when the magnetic field of the CH is stronger, when the distance between the CH and FR is smaller, and when the area of the CH is larger, consistent with the aforementioned observational studies. We also showed that the CH can act as an attractor. If the polarity of the FR is anti-aligned with respect to the CH, an approach to the CH occurs first, and then, the guidance of the CH magnetic field lines leads to the motion away from the CH.

On the other hand, in Sahade, A. et al. (2022), we analyzed how a PS influences the deflection of a FR. In this case, since the PS intrinsically possesses a region of minimum magnetic energy at its cusp -null point (NP)-, the presence of the FR creates another NP where the rope initially moves toward. However, we demonstrated that depending on the intensity of the magnetic field of the PS, the FR can move toward the NP of the PS, it can move away from this NP, or it may not eject.

Using this knowledge, in Sahade et al. (2023) we explain the anomalous trajectory of the famous Cartwheel Event, the CME suffers a double deflection due to the combination of a neighboring PS and CH.

4. Final Comments

These investigations highlight that the crucial factor for the initial deflection is the presence of regions of low magnetic energy. Subsequent alterations in the trajectory of the CME are attributed to the channeling of the ambient magnetic field. The anomalies observed in specific cases are further elucidated by considering the relative magnetic polarity between the CME source and the adjacent magnetic structure.

Nevertheless, observational studies show that within a dynamic and magnetically intricate coronal environment, there are additional factors to take into account. These include magnetic reconnections that modify the magnetic topology, the inertia or the twisting within the CME, and various other dynamical effects. Understanding these complexities is essential for unraveling the intricate dynamics of CME trajectories.

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Application of Deep Learning techniques in solar photosphere modeling

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This proceedings paper summarizes the research on the application of deep learning techniques in modeling the solar photosphere. The study explores the challenges of precisely modeling the complex and variable photosphere and introduces generative adversarial networks as an innovative approach to capture physical structures without direct reliance on MHD equations.

Recent leaps in observational technology, catalyzed by milestones like cutting-edge space telescopes, have propelled our understanding of the universe. Confronted with atmospheric constraints, modern astronomical instrumentation and projects have tackled the challenge, despite significant expenses and intricate construction. In pursuit of nimble alternatives, current investigations delve into the fusion of artificial intelligence (AI), specifically leveraging deep learning techniques. Neural networks have demonstrated potency in diverse domains, from medical diagnostics and smart marketing to autonomous driving and secure data encryption.

Our work provides a comprehensive overview of research focused on applying deep learning techniques to model the solar photosphere, emphasizing the use of generative adversarial networks (GANs). We delve into the challenges associated with accurately representing the intricate and dynamic nature of the Sun's surface, introducing GANs as an innovative solution that doesn't rely directly on MHD equations. In particular, we are interested in exploring the use of deep learning techniques for generating solar photospheric structures based on numerical simulations from the MURaM code. With a specific use of Convolutional Neural Networks (CNNs) and GANs, the study aims to efficiently produce realistic images of complex solar phenomena. The primary objective is to develop GANs tailored for solar photosphere modeling. The methodology encompasses data collection from various solar instruments, with a detailed exploration of the proposed DCGAN (Deep Convolutional Generative Adversarial Network). This includes the 3D structure, training process, and physical implications, such as incorporating magnetic field divergence into the loss function. Multiple experimental runs are conducted to validate the proposed configurations and explore various physical conditions, resulting in visually appealing and physically accurate outcomes (Fig.1). The obtained results showcase remarkable performance, surpassing traditional methods and underscoring the potential of GANs in capturing intricate patterns within the solar photosphere. Quantitative validation metrics, visual representations, and comparisons with traditional methods further substantiate the robustness and superiority of the deep learning

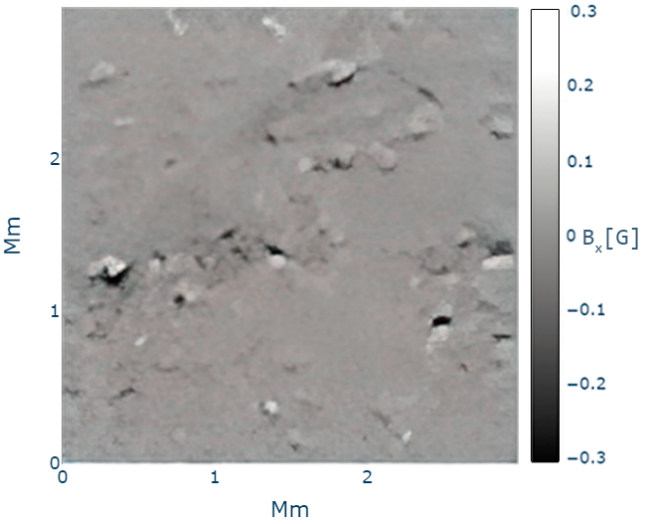

Figure 1. Magnetogram of a magnetic field cube generated by the DCGAN, the activation functions of the network generate normalized magnetic field magnitudes ranging from -1 to 1 Gauss (rescaled to -0.3 to 0.3 Gauss in the figure).

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approach. The results highlight the computational efficiency of the models, suggesting practical implications for real-time solar observation and modeling.

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Synthesis and inversion of Stokes parameters in the solar context applying Deep Learning Techniques

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The solar photosphere is the optical limit for which we can observe the sun at a greater depth. It is here where the structures generated by plasma convection to the solar interior are evident. The study of the phosphosphere allows us to analyze the emergency zones of magnetic fields, whose evolution can generate highly energetic phenomena such as flares, and turbulent movements that can be one of the causes of nanoflare generation. Although observations of the Sun are limited by the resolution of telescopes, during the last two decades an increasing number of realistic simulations of the configuration of the solar interior and atmosphere have been developed, which employ the equations of the magnetohydrodynamics and various other conditions, depending on the particular characteristics and activity in each zone of the sun, whereby the physical properties and details of the structure of various solar zones can be studied. In this work, the MURaM code is used to generate simulated physical parameters such as plasma density, temperature and velocity, including also the magnetic field, at different optical depths in the convective zone and the solar photosphere. The main objective, based on the simulations, is to train a 1D convolutional neural network, which takes the values of density, temperature, magnetic field and speed, the latter two in the line of sight, along a column. The trained network is capable of generating the corresponding Stokes parameters. Based on this model, another version is created which has an inverse functionality such that now having the Stokes parameters as inputs, the corresponding physical parameters of the plasma and the magnetic field in the same domain can be recovered.

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The effect of cross-section expansion on the evolution of coronal loops

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Solar coronal dynamics is strongly dominated by the magnetic field. The presence of loop structures, observed in Extreme Ultraviolet and X-ray images of active regions, are the most conspicuous manifestations of this. The "frozen-in" condition of the coronal plasma obliges it to flow along magnetic field lines making magnetic strands and loops the basic blocks of the coronal structure. This led, in recent decades, to a growing interest in studying the geometric and dynamic properties of these loops, in particular, in relation to the problem of coronal heating. In this work, we use a one-dimensional hydrodynamic code to analyze how the loop geometry, determined by the expansion factor of its cross-section, affects the evolution of the plasma contained in them. For that, we apply different geometries and heating regimes to modeled loops for later comparison with actual observations. Our preliminary results show that the evolution of the plasma parameters, mainly the density, are remarkably affected by different schemes of cross-section variation along the loops. This, in turn, produces clearly identifiable differences in the observational signatures of the parameters, as can be deduced from the analysis of synthetic spectral lines obtained from the models.

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Intermittent features in the solar wind: a case study

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The solar wind (SW) is a natural scenario to study intermittency in magnetohydrodynamic (MHD) turbulence for systems with low dissipation rates. These intermittent structures can be characterized by computing the degree of phase correlation of the magnetic field. In this work, we study in situ observations of magnetic field intensity, velocity, and proton density from the Advanced Composition Explorer spacecraft ACE, which is located near one astronomical unit from the Sun, in the SW near Earth. We obtained spectral indices and flatness scaling exponents of the studied fields characterizing their intermittent features.

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Assessing the predictability of solar active regions using helioseismic holography: An exploratory data analysis

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For solar astrophysics and space weather, deepening our understanding of the relationship between solar Active Regions (ARs) and solar flares is essential to predict and mitigate their effects on our planet. This study focuses on assessing the possible connection between ARs on the far side of the Sun, identified through holographic helioseismology techniques, and the ARs that rotate onto the visible side of our star, the near side. Using Doppler observations from the Solar Dynamic Observatory (SDO), the Northwest Research Associates (NWRA), in collaboration with Stanford University, regularly generates acoustic maps of the far side of the Sun (one map every 12 hours), allowing us to analyze non-visible ARs from Earth. This poster will present exploratory data analysis of ARs in the identifiable regions on both the far and near sides of the Sun, covering the period from April 25, 2010, to July 31, 2023. The list and characteristics of active regions on the visible solar disk are taken from standard catalogs compiled by the National Oceanic and Atmospheric Administration (NOAA) for this purpose. The analysis aims to assess the existence (or lack thereof) of a relationship between active regions on the far side of the Sun and those that become visible due to the rotation of our star. We analyze key parameters such as acoustic intensity and morphological evolution of active regions, to then visualize them and carried out descriptive statistical techniques to evaluate potential statistical correlations among them. This exploratory data analysis is the first step of a broader project that seeks to use the acoustic characteristics of the Sun's far side as predictors of subsequent solar flares on the visible side of our star.

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Terrestrial influence of solar activity: The September 1941 solar storm and its relationship with unexplained terrestrial events

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Solar activity refers to the various phenomena that occur on the Sun, including sunspots, solar flares, and coronal mass ejections (CMEs), mainly driven by the highly dynamic and complex Sun's magnetic field. The influence of the Sun on our planet is a fascinating and relevant topic, as solar activity can have significant effects on our environment and many technologies of our contemporary society. In this research work, we explore the relationship between solar activity and various events that occurred on Earth, focusing on the solar storm that took place in 1941. This research focus on preliminary findings and discuss the implications and prospects for future investigations in this field. Our research delves into the intriguing possibility that the intense solar storm of September 1941 may have played a pivotal role in triggering unexplained terrestrial events, including some mysterious explosions. By exploring this hypothesis, we aim to uncover new insights into the complex interplay between solar activity and its terrestrial impacts, particularly in the context of historical events that have remained enigmatic for decades. Central to our hypothesis is the concept of Faraday induction, whereby changes in the local magnetic flux during the geomagnetic storm could have induced currents in the wires connected to dynamite blasting caps. The exact magnitudes of magnetic flux changes capable of potentially triggering the detonation of the explosives during the geomagnetic storm are not definitively established. While our preliminary investigations suggest a potential connection between the solar storm and the unexplained terrestrial events, further in-depth research is needed to solidify the precise link.

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Study of magnetic field variations in high-cadence vector magnetograms during solar flares

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During a flaring event, the magnetic field topology changes rapidly, abruptly, and significantly. Some of these eruptive events inject enough energy into the photosphere and sub-photosphere to generate acoustic responses observed as sunquakes. The precise physical mechanism causing the acoustic source of a sunquake is still a topic of debate. A number of authors agree that magnetic field restructuring must play a fundamental role in causing such acoustic drivers. Previous studies have mainly probed the line-of-sight component of the magnetic field in such scenarios. In this work, we investigate the temporal and spatial evolution of the permanent changes in the magnetic field during 4 flares from high-cadence vector magnetograms (135 to 720 s) of the imaging system (dopplergrams and magnetograms) of the SDO/HMI instrument, which are suitable for investigate the phenomenon. These highly energetic events occurred during the current solar cycle 24, in a range of high and low energy, according to the GOES classification. Changes of tens of degrees in the magnetic field inclination are present in the studied flaring events displaying sunquakes. The acoustic wave is produced in the lower atmosphere by the ponderomotive force in the Alfvénic front associated with the magnetic variation. The analysis carried out represents a crucial input for the investigation of sunquake's origin and dynamics. We conclude that permanent changes in the magnetic field with values greater than 10 degrees in a kernel, are likely to induce sunquake signatures. Injection of particles seems not to take place when the field lines do not display the correct direction (downwards). Our results are in agreement with previous theoretical approaches. Sunquakes offer and opportunity for studying the interaction of acoustic waves with magnetic fields and flows in flaring active regions.

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Dust filtration in revenant protoplanetary disks (Invited contribution)

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Keywords: *planets and satellites: formation, protoplanetary discs, stars: evolution*

Abstract

Estrellas más masivas que el Sol, con masas entre 1.5 y $3M_{\odot}$, experimentan transformaciones notables en su estructura interna y temperatura efectiva durante los primeros millones de años de su existencia. Estos cambios afectan considerablemente a los discos protoplanetarios que se forman a su alrededor, impactando en los procesos de formación planetaria. Aquí investigamos los efectos de la evolución estelar en la evolución simulatánea de gas y sólidos en un disco renacido que orbita una estrella de $2.5M_{\odot}$. Este escenario ha sido descripto recientemente por Ronco et al. (2024), representando la reconexión de los discos interno y externo generada después de la apertura de una brecha debido a la fotoevaporación por la estrella central. Nuestras simulaciones muestran que, como era esperable, esta brecha también divide el disco sólido en dos, inhibiendo la migración radial de polvo/gravas desde las regiones externas, lo que podría limitar la formación de núcleos masivos cerca de la estrella. Sin embargo, una vez reconstruido el disco, el flujo de polvo/gravas se reactiva permitiendo que nuevo material alcance las regiones internas que podría contribuir a una formación tardía de Súper-Tierras.

Resumen

Stars more massive than the Sun, ranging between 1.5 and $3M_{\odot}$, undergo notable transformations in their internal structure and effective temperature within the first million years of their existence. These changes significantly affect the protoplanetary disks that form around them, impacting the processes of planetary formation. We here investigate the effects of stellar evolution on the simultaneous evolution of gas and solids in a revenant disk orbiting a $2.5M_{\odot}$ star. This scenario has been recently described by Ronco et al. (2024), portraying the reconnection of the inner and outer disks generated after a gap is opened by photoevaporation from the central star. Our simulations show that, as expected, this gap also divides the solid disk into two, inhibiting the radial drift of dust/pebbles from the outer regions, which may constrain the formation of massive cores near the star. However, once the disk is reconstructed, the dust/pebble flux is reactivated, enabling fresh material to reach the inner regions that could contribute to a late formation of Super-Earths.

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1. Introduction

Stellar evolution has been found to be a key ingredient in the evolution of protoplanetary disks around intermediate-mass stars. The dissipation timescales decrease as the mass of the central star increases, but the disk pathways show the typical inside-out disk evolution for all stellar masses Kunitomo et al. (2021). Ronco et al. (2024) expanded Kunitomo et al. (2021)'s work considering the effects of stellar evolution and adopting a finer grid of disk parameters, such as different disk masses and viscosities. These authors found that the evolutionary pathways of the gas disk in fact depend on the stellar mass, changing from the typical inside-out, to an homogeneous and to an outside-in evolution as the mass of the star increases. A particular pathway named "revenant disk evolution", has been found between the last two. In this scenario, and as a consequence of the changes of the X-ray and FUV photoevaporation rates

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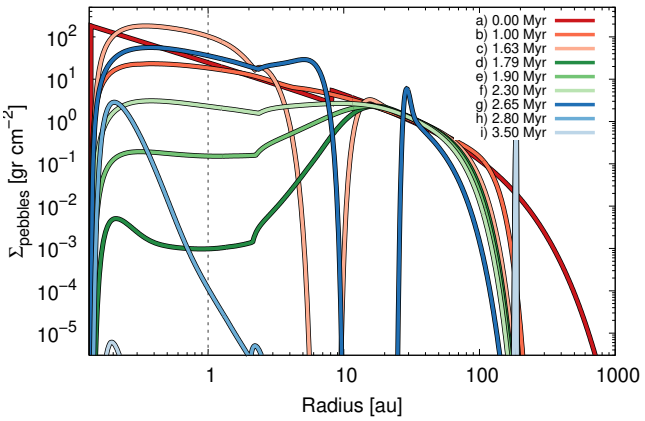

Figure 1. Time evolution of the solid surface density profiles for the disk case S33 (Ronco et al., 2024) for 1 mm pebbles. Each profile has a correspondence with the gas disk profiles of the revenant disk stages I, II and III, respectively, described in Sec. 3.4 of Ronco et al. (2024).

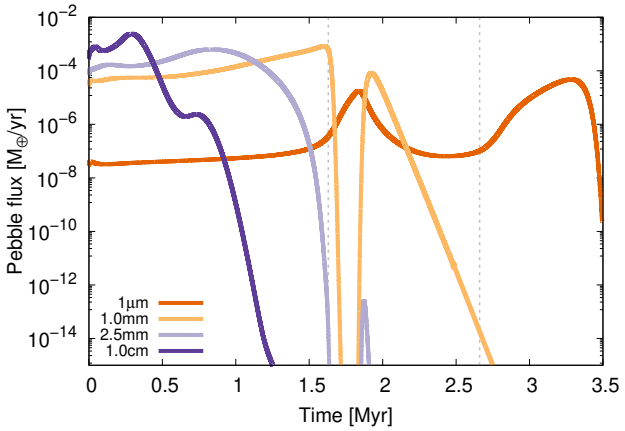

Figure 2. Time evolution of the dust/pebble flux of the revenant disk case S33 (sec. 3.4 in Ronco et al. (2024)) for different dust/pebble sizes, computed at 1 au. The gray dashed vertical lines represent the times at which the gap opens in the disk due to X-ray and FUV photoevaporation, respectively.

due to stellar evolution, the gas disk is reconstructed after the first gap opening by X-ray photoevaporation. We here explore how this particular case affect the evolution of the solid component of the disk and thus, on planet formation.

2. The model

The evolution of the gas component of the protoplanetary disk is computed as in Ronco et al. (2024). Because the dust/pebbles are strongly coupled to the dynamics of the gas, the time evolution of the dust/pebbles surface density is computed by solving a diffusion-advection equation,

$$\frac{\partial \Sigma_p}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}\left(r\, v\, \Sigma_p\right) - \frac{1}{r}\frac{\partial}{\partial r}\left[r\, D^*\, \Sigma_g \frac{\partial}{\partial r}\left(\frac{\Sigma_p}{\Sigma_g}\right)\right] = \dot{\Sigma}_p, \quad (1)$$

where Σ_g and Σ_p are the gas and the dust/pebbles surface density, respectively, v the drift radial velocity, D^* the dust diffusivity and $\dot{\Sigma}_p$ the sink term due to dust/pebble sublimation (see details of the model in Venturini et al., 2020; Guilera et al., 2020). To keep this study as simple as possible, we do not compute the dust/pebble growth. Solids are always characterized by a single size along the disk and at every timestep. We run simulations only for the revenant disk case S33 (see sec. 3.4 in Ronco et al., 2024) and considering dust of 1 μm or pebbles of 1 mm, 2.5 mm and 1 cm. The initial dust/pebbles surface density takes into account the water-ice sublimation at the iceline, and the dust-to-gas ratio is taken as 1%.

3. Results

Figure 1 shows the time evolution of the solid surface density profiles for the disk case S33 formed by 1 mm pebbles. The first gap opened in the gas disk due to X-ray photoevaporation (see fig. 5 in Ronco et al., 2024) also opens a gap in the pebble surface density at 1.63 Myr (profile c). This gap limits the pebble flux from the outer region of the disk towards the inner ones as long as the gap exists. However, once the disk is reconstructed due to the combination of a strong decay in the X-ray photoevaporation rate and viscous evolution (profile d), pebbles drift inwards reaching the inner regions later on.

Figure 2 shows the time evolution of the pebble flux computed at 1 au for different solid particle sizes. For pebbles of 1 mm, the pebble flux abruptly decays just after the first gap opening (first dashed vertical gray line) but is reactivated once the disk is rebuilt, which may contribute to the late formation of Super-Earths at ~1 au. However, the reactivation of the pebble flux depends on the particle sizes since this parameter is directly related to the radial drift velocity (see the recent review by Birnstiel, 2024). Particles smaller than 1 mm have drift velocities low enough not to empty the outer zones of the disk of solid material before the time of the first gap opening. For this reason, once the disk is reconstructed, there is still solid material that can flow towards the central star. On the other hand, particles with sizes greater than 1 mm have higher drift velocities. This causes the disks to lose most of its solid material rapidly before the time of gap opening. Subsequently, there is no longer material available in the outer regions to supply the inner ones after the disk reconstruction.

4. Conclusions

For particles with sizes lower than ~1 mm we find pebble filtration in reventant disks. This pebble filtration towards the inner regions could promote the late formation of Super-Earths.

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Orbital resonances in planetary systems (Invited contribution)

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Keywords: *exoplanets, orbital resonances*

Abstract

Orbital resonances are dynamic mechanisms characterized by a strength capable of overcoming other perturbations, managing to maintain the planetary systems captured in the resonant configuration. They are located at some specific values of the semimajor axes but they occupy a non-negligible region of that space. The existence of a certain resonant width added to the fact that there are mechanisms that lead to resonances (through orbital migration for example) makes resonant systems frequent. We show here some applications of the semi-analytical model of Gallardo et al. (2021) which is especially good for eccentric and inclined systems.

Resumen

Las resonancias orbitales son mecanismos dinámicos caracterizados por una fuerza capaz de superar otras perturbaciones, logrando mantener los sistemas planetarios capturados en la configuración resonante. Se ubican en ciertos valores específicos de los semiejes mayores pero ocupan una región no despreciable de ese espacio. La existencia de un determinado ancho resonante sumado a que existen mecanismos que conducen a resonancias (a través de migración orbital por ejemplo) hace que los sistemas resonantes sean frecuentes. Mostramos aquí algunas aplicaciones del modelo semianalítico de Gallardo et al. (2021) que es especialmente bueno para sistemas excéntricos e inclinados.

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1. Mean motion resonances

A stable planetary system has a certain number of fundamental frequencies which are constant and related to the orbital evolution of the planets. High frequencies are given by the orbital periods and low frequencies are defined by the secular evolution of the orbits. Orbital resonances in planetary systems occurs in two flavors: secular resonances and mean motion resonances (MMRs). Secular resonances occur when there are commensurabilities involving the low frequencies. MMRs between planets 1 and 2 occur when there is a commensurability between the planetary orbital periods or mean motions, n. So, we have $k_1 n_1 - k_2 n_2 \simeq 0$, (e.g. $2n_1 - 3n_2 \simeq 0$) were the k_i are integers. A more sensible indicator of the resonant state is the critical angle $\sigma = k_1\lambda_1 - k_2\lambda_2 + \gamma$ which involves positions (λ) instead of angular velocities (n). When two planets are trapped in MMR their mutual perturbations make their orbits to oscillate (librations) with periods of the order of $\sim 10^2$ orbital periods. Their semimajor axes a_i oscillate and σ also does. MMRs are not an instantaneous effect but a cumulative effect of synchronized planetary perturbations that makes the orbits librate due to a kind of forced mode providing stability against other perturbations. MMRs are very common among planetary systems because planets migrate due to cosmogonic reasons or physical reasons and eventually they fall in resonance. We know the extreme cases of resonant chains with several planets in resonance like TRAPPIST-1 or HD 110067. Several planetary systems exhibits some offset (Charalambous et al., 2022) being the Solar System one of them because the giant planets are close but outside mutual MMRs. Michtchenko & Ferraz-Mello (2001) showed that the Jupiter-Saturn configuration in the exact resonance makes the planetary system chaotic, so the transition to a resonant configuration from one non resonant cannot be done for free. We have also examples of

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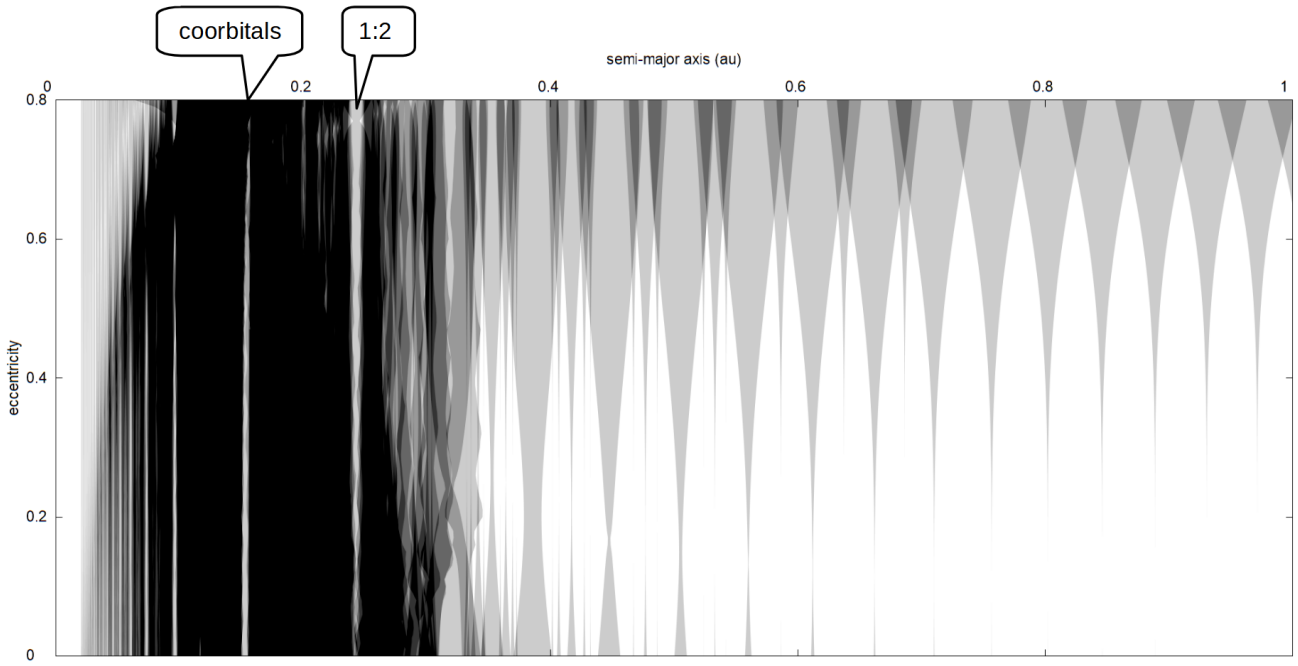

Figure 1. Resonance domain in the space (a, e) of a 1 $m_\oplus$ planet coplanar with the very eccentric planet TOI-3362b. Each resonance domain is painted in grey. Dark regions correspond to resonance overlap. Resonances 1:1 and 1:2 are labeled. The structures dominating the right region correspond to resonances 1:N exterior to TOI-3362b. $\sim$ 300 resonances are showed in this plot.

the contrary situation: Gallardo et al. (2021) showed that the HD 31527 system only can be stable if the two external planets are inside the 16:3 resonance.

There exist MMR models for coplanar and low eccentricities orbits but not models for arbitrary planetary orbits. In order to massively explore the properties of the planetary resonances we proposed a simple model (Gallardo et al., 2021) that works very well for all resonances, arbitrary (e, i), can easily calculate hundreds of resonances and its codes are for non-experts. For example, the model predicts that the libration amplitudes of the planets verify

$$\frac{\Delta a_1}{\Delta a_2} \sim \frac{m_2}{m_1}\left(\frac{k_1}{k_2}\right)^{4/3}$$

that means less massive planets have larger libration amplitude. A recent example of the application of the model to the planetary resonance $1n_1 - 2n_2$ can be found in Giuppone et al. (2023). Codes and materials can be found at https://sites.google.com/view/mmresonances.

2. The case of TOI-3362

According to Dong et al. (2021) this sytem is composed by a star with $M = 1.445 M_\odot$ and a planet with $m = 5 M_{Jup}$, $a = 0.153$ au, $e = 0.815$.

Applying the model we studied the resonances with an hypothetical 1 Earth mass planet. The results are shown in Figure 1. Each resonance domain in (a, e) of the 1 $m_\oplus$ planet is plotted in grey. We show interior and exteriors resonances. Dark regions correspond to resonance overlap which is an indicator of chaos. There is a strong chaotic region close to the giant planet but with apparently at least two non perturbed regions inside: coorbitals and planets in the 1:2 resonance. For this last case we tested the stability with MEGNO indicator (Cincotta & Simó, 2000), dynamical maps and direct numerical integration of the full equation of motions and confirmed that planets remain stable by at least for $\sim 10^4$ orbital periods. In cases of planetary systems like this one with extreme eccentricities we can predict the properties of mutual resonances very well, but the long term evolution depends crucially on their mutual inclination, which is an undetermined parameter.

3. Conclusions

The model works very well even for high eccentricity cases and when accompanied by dynamical or chaos maps a good dynamical characterization can be obtained. It seems that systems cannot enter or exit a resonance without a dynamic crisis. Why are some resonant systems stable and others unstable? More studies of MMRs with eccentric planets and more secular resonant evolution studies in the spatial case are needed to answer these questions.

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Gaia's view of hydrated asteroids

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Keywords: *asteroids: general, minor planets*

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We analyze Gaia DR3 asteroid reflected light spectra in an attempt to detect the shallow absorption band around 0.7 μm, which is indicative of primitive aqueous alteration.

Gaia DR3 contains reflectance spectra for 60 518 asteroids (Gaia Collaboration et al., 2023). We analysed these spectra in an attempt to detect the feature around 0.7 μm which indicates that in the asteroid's parent body liquid water was present at some point (e.g. Fornasier et al., 2014). In combination with the asteroid orbital elements, an analysis of this feature can provide insights into where hydration (i.e. water) was present in the primitive solar system.

We used machine learning to identify asteroids with a 0.7 μm band. All Gaia DR3 reflectance spectra were used as input data. The normalized reflectance at the bluest wavelengths was corrected as described in Tinaut-Ruano et al. (2023). Literature classifications were collected for a sample of 1134 asteroids. The classifications were verified by JB and MB on the basis of spectra from the literature. This resulted in 315 C-type asteroids, of which 140 asteroids have the 0.7 μm band and in 139 the band is not present (the remaining C-types being dubious cases). Furthermore there are 569 S/X/Other type asteroids and 233 asteroids of unknown or doubtful taxonomic class. The asteroids with literature classifications were used to train a two-stage machine learning algorithm (scikit-learn's multilayer perceptron classifier[1]) which first separates C-type asteroids from the rest and then identifies asteroids with a 0.7 μm band from among the C-types. The observational uncertainties were accounted for by running the classification algorithm on multiple random realizations of the data (assuming Gaussian uncertainties). In both classification steps asteroids with mean class probabilities above 0.8 and a scatter in the probabilities of less than 0.1 were retained as C-type and hydrated asteroids, respectively. Some 2200 C-type asteroids were identified of which 230 feature the 0.7 μm band, $\sim$ 400 have no h-band, and the rest could not be confidently classified. Figure 1 shows the fraction of C-type asteroids with the 0.7 μm band as a function of proper semi-major axis and H-magnitude (Asteroid physical properties were obtained from https://mp3c.oca.eu/). The fractions are significantly lower than those found by Rivkin (2012), and should be seen as lower limits. No hydrated asteroids were identified for $a_p < 2.1$.

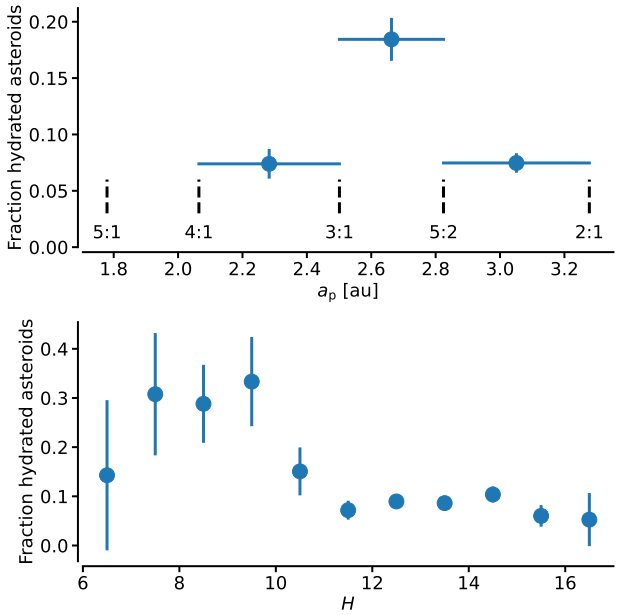

Figure 1. Hydrated asteroid fraction with respect to all C-types vs. semi-major axis (top) and H-magnitude (bottom). The fractions as a function of semi-major axis are for ranges in a_p in between the indicated mean motion resonances. The error bars refer to Poisson uncertainties.

[1] https://scikit-learn.org/stable/

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The results are still very preliminary. Future work will focus on improving the identification of asteroids with the 0.7 μm feature in their reflectance spectra and accounting for selection effects.

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Feedback-limited variable accretion on to planets

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Keywords: *accretion, accretion discs, hydrodynamics, planet-disc interactions, protoplanetary discs*

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Accretion on to giant planets triggers a feedback process, which increases its variability. Feedback variability appears as broadband noise, which can be distinguished from eccentricity-induced variability. The heating of the gap may reduce dust concentration.

Protoplanetary discs, and their interaction with forming planets, are typically modelled using hydrodynamical simulations. These models were originally developed with a local isothermal approximation, meaning that the temperature is prescribed as a fixed function of distance from the central star.

Many observed discs show hot spots, which are likely due to giant planets growing within them. The giant planet accretes gas from its surroundings. This results in an accretion luminosity from the planet. The liberated energy heats the surrounding gas and alters its dynamics. In these cases, the locally-isothermal approximation does not hold.

Montesinos et al. (2015) modified the 2D hydrodynamics code FARGO-AD (Baruteau & Masset, 2008) implementing a term that accounts for the heating around a growing planet. In that early work the planet luminosity was a free parameter. Using a value of $10^{-4}L_{\odot}$, Montesinos et al. (2015) found that the surroundings get temperatures ~ 300 K, which produces a thermal emission in L' of the order of a millijansky, comparable to observed hot spots.

The planet luminosity however does not need to be a free parameter. Instead, it should be set by the accretion on to the planet, in a *feedback* process. Gárate et al. (2021) implemented this in the code, making the planet luminosity proportional to its accretion rate. The higher temperature close to the planet produces a larger pressure gradient, which reduces the density at that location, and therefore the accretion rate. However, we found that the feedback still allows up to $10^{-3}L_{\odot}$ planet luminosities, without halting accretion. The process also creates vortices, which propagate and make the accretion rate more variable.

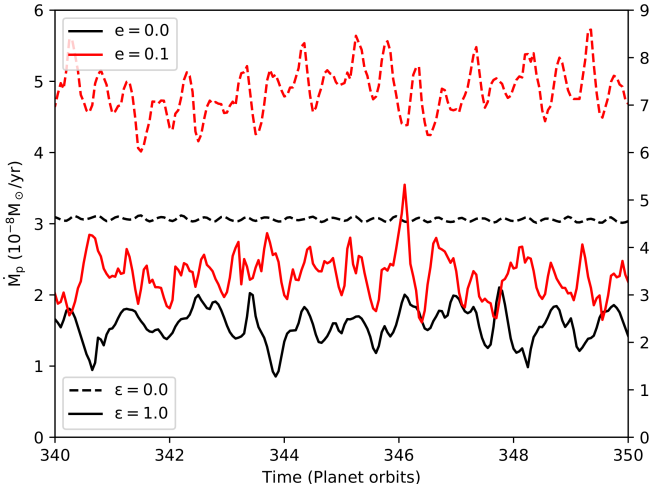

Figure 1. Accretion rate curves for models with and without feedback implemented ($\varepsilon = 1$ and 0), for different orbital eccentricities ($e = 0$ and 0.1) (Gárate et al., 2021).

Figure 1 shows that the amplitude of the accretion rate variability is similar to that of a planet in an eccentric orbit. However, the models with feedback seem more stochastic. We quantified this by calculating the accretion power spectra (Arévalo et al., 2012), which confirms that accretion induces a higher broadband noise, compared to the well-defined periodic peaks produced by an eccentric orbit.

Finally, we notice that feedback increases the gas pressure inside the gap carved by the giant planet, decreasing the pressure gradient at its edges. This results in a velocity profile for the gas which is closer to Keplerian. This may have consequences for the dust, which will suffer a slower drift and perhaps reduce its accumulation at the outer edge of the gap. We plan to quantify this process in a follow-up work.

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Mid-infrared spectra inform on the complexity of extrasolar dust clouds

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Keywords: *brown dwarfs, infrared: stars, stars: atmospheres*

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Crucial knowledge about dust clouds in substellar atmospheres comes from Spitzer observations. We summarize here what we have learned about the formation, composition, evolution, and distribution of dust clouds from the analysis of the silicate absorption in Spitzer mid-infrared spectra.

The emergent spectra of the warmest brown dwarfs and exoplanets are shaped by dust clouds in their atmospheres. Therefore, understanding these objects depends on our knowledge of dust clouds. Despite many indirect studies on these clouds, the only *direct* evidence of the existence of dust clouds is a ∼9 μm silicate absorption. Prior to JWST, Spitzer was the only telescope able to observe this silicate absorption. We list here the lessons learned about dust clouds from analyses of the silicate absorption.

Dust clouds in substellar atmospheres:

- Comprise a combination of $\lesssim 1$ μm-sized amorphous silicate (enstatite, forsterite, quartz, and/or pyroxene) and iron grains (Cushing et al., 2006; Burningham et al., 2021; Luna & Morley, 2021; Vos et al., 2023; Suárez & Metchev, 2023).
- Are near ubiquitous in L-type atmospheres and form, then thicken, and sediment out of the photosphere in the $T_{\rm eff}$ range ≈2000–1300 K (Suárez & Metchev, 2022).
- Sediment less efficiently in young objects (Suárez & Metchev, 2023; Suárez et al., 2023).
- Are preferentially concentrated at the equator compared to the poles (Suárez et al., 2023).
- Are responsible for their color diversity (Cushing et al., 2006, 2008; Burgasser et al., 2008; Looper et al., 2008; Suárez & Metchev, 2022; Suárez et al., 2023, see Figure 1) and, potentially, their variability (Suárez & Metchev, 2022).

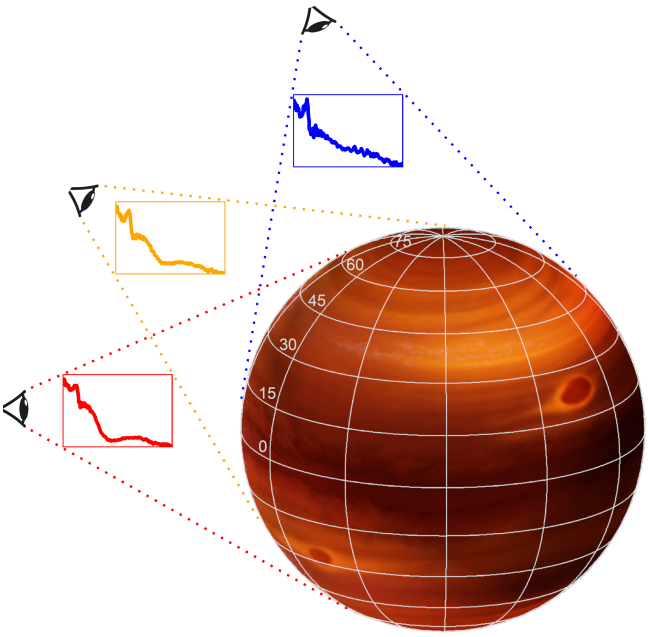

Figure 1. The appearance of substellar objects is highly influenced by their viewing inclination. Figure adapted from Suárez et al. (2023) to show that lower latitudes exhibit stronger silicate absorption and are redder.

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Three-Dimensional Modeling of Supersonic Gas Accretion and Ionized Envelope Dynamics in Jupiter-like Planets

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Keywords: *disk: circumplanetary disk, hydrodynamics: simulations, planets: planet feedback, planets: planet formation*

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We explore gas giant accretion in protoplanetary disks using 3D hydrodynamical simulations of a Jupiter-mass planet. Our model incorporates a non-isothermal energy equation for gas and radiation energy diffusion, enhanced by a novel radiative feedback mechanism from the planet. Key findings demonstrate supersonic gas accretion forming an ionized envelope around the planet, with its extent (0.2-0.4 of the Hill radius) influenced by radiative feedback. This ionization radius serves as a critical boundary for accretion dynamics, impacting the calculation of accretion rates and $H\alpha$ emission luminosities. We show that radiative feedback significantly increases accretion rates, especially inside the ionization radius. Accretion luminosities at this radius are substantially lower than at the Hill radius, providing new perspectives for interpreting current non-detections of $H\alpha$ emissions in planet formation.

We conducted FARGO 3D (Benítez-Llambay & Masset, 2016) numerical simulations to examine the evolution of Jupiter-like planets in a viscous disk, taking into account both gas and radiation energy transport and the radiative feedback of planets (Montesinos et al., 2015). A key discovery is the formation of an ionized envelope around these planets, characterized by an ionization radius that also marks the stopping point of supersonic gas accretion (Figure 1). This radius, fluctuating between 0.2 and 0.4 times the Hill radius, is significantly impacted by the inclusion of radiative feedback.

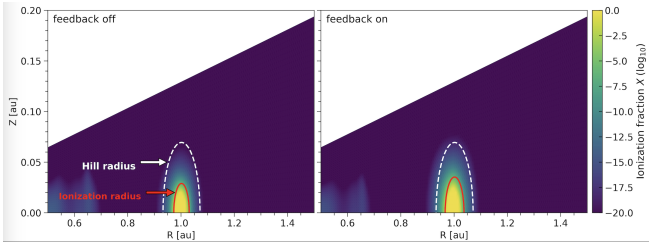

Figure 1. Representation of the ionization envelope around the planet, in Hill units, at the final stage of the models. This is for scenarios with and without radiative feedback, defined by ionization parameter values $X \geq 0.5$.

We observed that the radiative feedback enhances the accretion rate with a subsequent expansion of the ionization radius when the feedback is active (Figure 2). Comparing the accretion rates at the Hill sphere and the ionization radius, we found that a much smaller fraction of gas passing through the Hill sphere actually contributes to the envelope or reaches the planet's surface.

This study suggests that computing the accretion rate at the ionization radius, rather than at the Hill radius, is more effective for determining the luminosity associated with $H\alpha$ emissions. Our findings imply that the accretion

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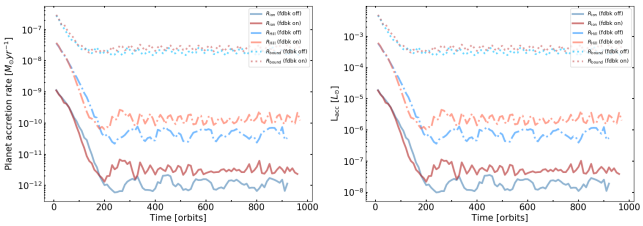

Figure 2. Planet accretion rate for models with and without feedback computed at different radii: ionization radius $R_{\rm ion}$, Hill radius $R_{\rm Hill}$, and bound radius $R_{\rm bound}$.

luminosity, and thus the $H\alpha$ luminosity, computed at the ionization radius is considerably smaller than previously assumed, based on calculations at the Hill radius. This has important implications for interpreting the non-detections of $H\alpha$ emissions in several protoplanetary disks (Zurlo et al., 2020) as indicators of ongoing planet formation.

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Resonant dynamics of close-in small Saturnian satellites and application to Pallene (S XXXIII)

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In this work we explore the orbital vicinity of the small moon Pallene through numerical integrations and phase space mapping. The results reveal that Pallene's orbit is currently located close to mixed inclination-eccentricity type associated with the 19:16 Enceladus-Pallene resonance.

Spitale et al. (2006) suggested that Pallene's orbit is disturbed by a 19:16 resonance with Enceladus with a critical angle given by $\psi_1 = 19\lambda_E - 16\lambda_P - \varpi_P - 2\Omega_P$, where λ represents the mean longitude, ϖ is the pericenter longitude, Ω is the longitude of the node ascending and the subscripts P and E refer to Enceladus and Pallene, respectively.

Muñoz-Gutiérrez et al. (2022) show that ψ_1 and $\psi_2 = 19\lambda_E - 16\lambda_P - \varpi_E - 2\Omega_E$ angles circulate with approximate periods of 3,870 and 9,130 days, respectively, indicating that Pallene's current orbit is not effectively trapped into the 19:16 resonance.

In this work, we mapped Pallene's orbital vicinity using spectral analysis. We constructed a dense grid of initial conditions varying the osculating semi-major axis and the osculating eccentricity of tens of thousands of Pallene clones perturbed by Enceladus. The physical parameters and initial conditions for each satellite were obtained from *Horizons* (https://ssd.jpl.nasa.gov/horizons/) considering the initial date January 1, 2016.

Figure 1(a) represents the dynamical map for 30,000 Pallene clones considering Enceladus as the main perturber. We can observe two vertical structures limited by darker bands (chaotic regions) which represent the domains for the Ψ_1 and Ψ_3 ($\psi_3 = 19\lambda_E - 16\lambda_P - \varpi_P - \Omega_E - \Omega_P$) multiplets associated with the 19:16 resonance. Our mapping shows that the orbit of Pallene (dark star) is close to the Ψ_2 multiplet associated with a type of corotation inclination resonance and a more detailed view of this region can be seen in Figure 1(b).

Figure 2 shows the temporal variation for geometric angles ψ_1, ψ_2, and ψ_3, for several initial conditions (a_0, e_0) of Pallene clones indicated in Figure 1(a) and in the plots (see Figure 2(d-f)).

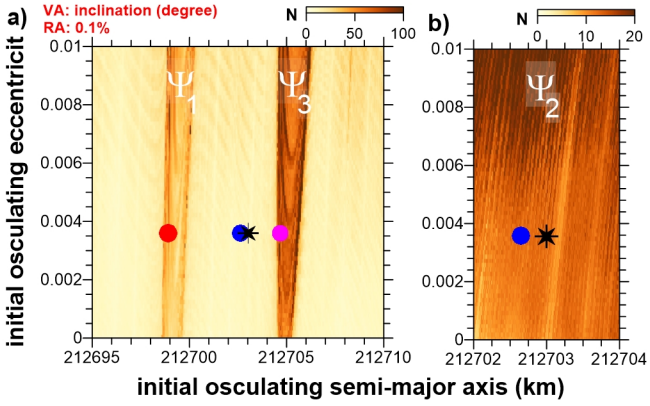

Figure 1. (a) Dynamical map of the Pallene vicinity revealing the 19:16 resonance multiplets. (b) A zoom into the domain of the multiplet Ψ_2.

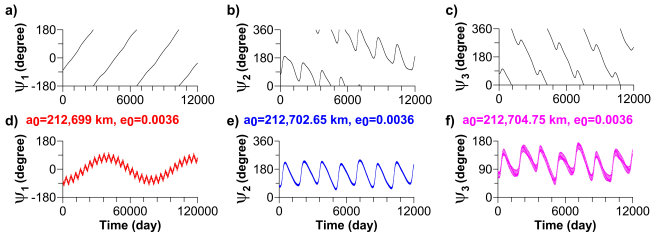

Figure 2. (a-c) **black star**: *Horizons* in the date 01/01/2016; (d) **red disk**: oscillation of ψ_1 around 0°; (e) **blue disk**: oscillation of ψ_2 around 135°; (e) **magenta disk**: oscillation of ψ_3 around 90°.

Conclusions: the current orbit of Pallene is not currently trapped into the 19:16 resonance involving Enceladus, but it is located close to its Ψ_2 multiplet which is located between Ψ_1 and Ψ_3 domains.

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Physical properties, source regions, and total mass flux of decimetre-sized aggregates around 67P/Churyumov-Gerasimenko

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Keywords: *comets: individual: 67P, methods: data analysis, methods: numerical*

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This study focuses on analyzing large solid aggregates ($\sim$ 10 cm) around comet 67P/Churyumov-Gerasimenko using data provided by the Rosetta mission. While the smaller particles were analyzed directly with the various on-board dust detectors, the larger particles were observed remotely only, so the information collected is sparse. To address this issue, a novel method is proposed. This method involves statistical comparison of the traces generated by the motion of the aggregates observed in OSIRIS images with those found in synthetic images, generated by modeling the trajectories of the aggregates. This made it possible to extract physical parameters of the aggregates, as well as information on their ejection mechanisms.

The first part of this work consists on the semi-automatic detection of tracks on images obtained by OSIRIS, the main imaging system onboard Rosetta, as described in Lemos et al. (2023). The images were acquired in five different sets between July 2015 (r_h = 1.32 au inbound) and February 2016 (r_h = 2.39 au outbound), totalling 189 images.

For each one of these real images, their synthetic counterparts were generated. These synthetic images are created by simulating the trajectory of the aggregates under the influence of comet and solar gravity, radiation pressure and gas drag. The gas flow description is the one presented by Marschall et al. (2020). The simulated trajectories depend on three aggregate properties, density ρ, radius r and initial velocity v_{in}, as well as the initial position on the comet surface.

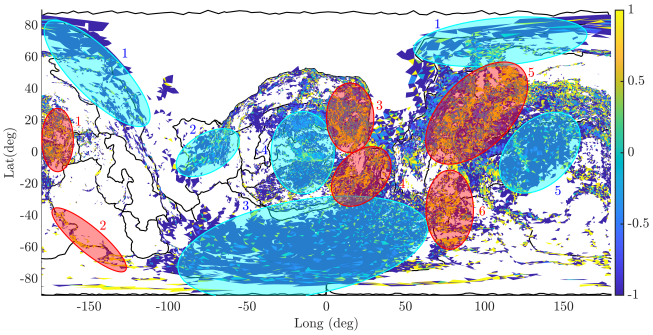

Figure 1. Map of the ejection efficiency regions on the surface of 67P. The high and low ejection efficiency clusters are shown with red and blue ellipses respectively.

Due to the movement of aggregates in front of the camera, they appear on the images as bright tracks instead of point sources. The last part consists on the comparison of the brightness, length and orientation of the observed tracks with the same properties of the synthetic ones. By selecting the aggregates that generate track properties distributions resembling the observed ones, we are capable of determining the aggregate properties and their spatial distribution on the surface.

We find that the aggregate properties are consistent among different epochs, with mean values $\rho \simeq 500$ kg m^{-3}, $r \simeq 10$ cm and $v_{in} \simeq 1$ m s^{-1}, similar to those reported in similar works (Pfeifer et al., 2024). Additionally, we were able to define the *ejection efficiency* as the probability of an aggregate coming from a certain position to generate a resembling track. The spatial distribution of ejection efficiency (Figure 1) is grouped in clusters of high and

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low ejection, related to heterogeneous and homogeneous terrain types respectively. This result is similar to the one presented by Vincent et al. (2016).

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Stellar activity or a planet? Revisiting dubious planetary signals in GJ581

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Keywords: *stars: activity, stars: individual: GJ581, stars: low-mass, techniques: radial velocities*

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We reanalyzed the radial velocities and spectroscopic activity indicators of GJ581, an M-dwarf harboring questionable planetary signals. Our analysis challenges the periodic signals previously identified as likely artifacts of stellar activity rather than planetary influence, reinforcing the need for cautious interpretation.

Magnetic activity alters the shape of spectral lines, leading to apparent radial velocity (RV) variations which can be periodic or quasi-periodic and can mimic planetary RV signals. These signals often manifest at the star's rotational period and its harmonics (Boisse et al., 2011). GJ581, an M-dwarf hosting a multi-planetary system, has a reported stellar rotation period of 132.3 ± 6.3 days (Suárez Mascareño et al., 2015). Notably, it displays two periodic signals attributed to planets d ($P_{\rm orb}$: 66.8 [d]) and g ($P_{\rm orb}$: 36.5 [d]), both harmonics of the stellar rotation period. This raises questions about whether these signals originate from planets or are artifacts of stellar activity.

To confirm or refute these signals, we used publicly RV data from HARPS, HIRES and CARMENES instruments, giving a total of 718 RV datapoints. Furthermore, we included activity indicators such as the $S-$ index, Hα, Na ID.

By modeling Hα timeseries using Gaussian Process (GP) regression with a quasi-periodic (QP) kernel, we derived GJ581's stellar rotation period ($P_{\rm rot} = 132^{+1.82}_{-1.71}$ days), improving the accuracy compared to the literature value.

We computed the Generalized Lomb-Scargle (GLS) periodogram of the RVs, identifying periodic signals corresponding to planets: b ($P_{\rm orb}$: 5.37[d]), c ($P_{\rm orb}$: 12.9[d]), d ($P_{\rm orb}$: 66.3[d]), and e ($P_{\rm orb}$: 3.14[d]). For the other literature planets f and g, the periodogram does not show significant signals attributable to those planets.

We employed Keplerian models to the RVs for the period of planets b, c and e. The best Keplerian fit is presented in Table 1. Then we analyze the temporal stability of the residual signal from the (3-)Keplerian model using the stacked Bayesian GLS (sBGLS) periodogram (Mortier & Collier Cameron, 2017). The level of confidence in detecting a planetary signal should increase with additional data. However, Fig.1 shows that the probability around the 66-day signal attributed to planet d does not steadily rise with an increasing number of observations. Instead, it is

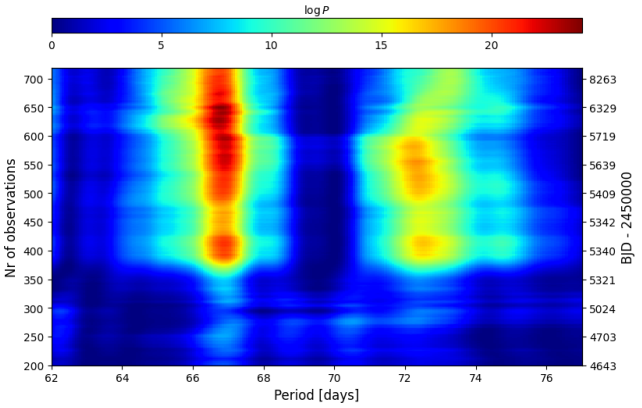

Figure 1. sBGLS periodogram of the RVs residual from the (3-planet)Keplerian model.

Planet	Period (days)	K(m/s)	$M_p(M_\oplus)$
b	5.36861±0.00002	12.39±0.07	15.5±0.6
c	12.9180±0.0004	3.49±0.07	5.9±0.2
e	3.14880±0.00004	1.56±0.08	1.6±0.1

Table 1. GJ581 orbital parameters derived from (3-) Keplerian model. K is the semi-amplitude of the signal and M_p is the mass of the planet in Earth masses.

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alongside another signal around 72 days, with a pattern consistent of a stellar activity-induced signal.

Motivated by this, the next step is performing a simultaneous RV (Keplerian model) and activity indicators (GP+QP kernel) analysis to determine if the 66- day signal can be described by stellar activity.

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In search of the "Missing Mass": Measuring protoplanetary disk dust masses with ALMA

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Keywords: *circumstellar matter, planetary systems, stars: statistics, stars: variables: T Tauri, Herbig Ae/Be, submillimetre: stars*

Protoplanetary disks are an essential component of the planet formation process. The number and size of planets in a system are directly constrained by the amount of dust and gas in the disk. We present disk dust masses ($M_{\rm dust}$) measured using spectral energy distribution (SED) modeling of 15 disks around T Tauri stars (TTS) in the Serpens star-forming region, using ALMA 1.33mm fluxes from the literature. Calculated $M_{\rm dust}$ are a factor of ∼1.5 higher than those reported in the literature. Most works assume the disk to be optically thin at all mm wavelengths whereas our modeling finds that disks may be partially optically thick at these ranges. Our results show that disks around Serpens' TTS may not have enough material to form planetary systems and do not completely alleviate the "missing" mass problem, known as the reported discrepancy between the available mass in protoplanetary disks and the observable mass in exoplanet systems.

We calculated disk M_{dust} for a sample of 15 TTS located in the Serpens star-forming region using multi-wavelength photometry and Spitzer IRS spectra, and by modeling their SEDs following Ribas et al. (2020). The sample was obtained from an ALMA band 6 survey of Serpens (Anderson et al., 2022). The aim is to compare SED-derived Mdust (that account for the effect of optical depth) with mm-flux- derived measurements. The key findings of this work are as follows: [1] SED-derived $M_{\rm dust}$ are ∼1.5 times higher than literature values (see Figure 1); [2] The sample has a greater median $M_{\rm dust}$ than the populations' shared average of 11 star-forming regions (0.5-10 Myr Rilinger et al., 2023); [3] $M_{\rm dust}$ depletion is low, characteristic of younger regions (1-3 Myr) and follows $M_{\rm dust} \propto t^{-1}$; [4] Serpens' class II objects do not have enough material in their disks to solve the "missing mass" problem.

Our results show how SED-derived $M_{\rm dust}$ can constrain disk properties. This method allows for a broader study of diverse regions (environment and age). Future ALMA surveys can benefit this en- deavor as (sub)mm observations can constrain the disk's dimensions and increase the accuracy of the SED-modeling process. Thus providing a detailed view of the disk evolution timeline and a better understanding of the planet formation process that with the explosion in exoplanet detection is of high interest.

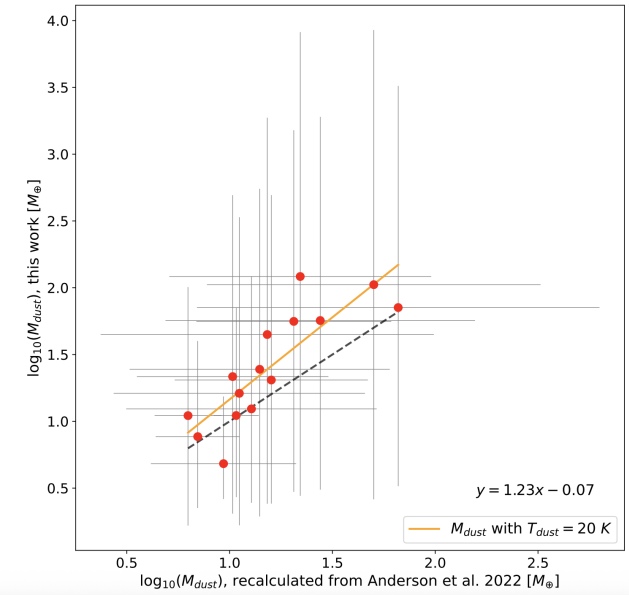

Figure 1. SED-derived $M_{\rm dust}$ vs literature $M_{\rm dust}$ (Anderson et al. 2022). The panel displays a linear fit (solid orange line) to the comparison to dust masses recalculated assuming a constant dust temperature of 20 K. The black dotted line denotes a 1-to-1 fit. The line equation is displayed for the linear fit.

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Simulation of potentially habitable environments on the surface of exoplanets

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Keywords: *H II regions, ISM: jets and outflows, stars: mass loss, stars: pre-main sequence*

In this work, we simulate analogous environments to those expected to be found on the surface of Proxima b, considering atmospheric composition and ultraviolet (UV) radiation. We investigated the survival rates of the yeast *Rhodotorula dairenensis* under these conditions.

Proxima b is an exoplanet with 1.17 $M_\oplus$ (Suárez Mascareño, A. et al., 2020) (Mascareño et al. 2020) and is in the habitable zone of an M dwarf. Such stars are interesting for astrobiology studies as they host the majority of terrestrial exoplanets already discovered in habitable zones. However, they are challenging in the biological context due to high levels of stellar activity, presenting frequent and intense flares with high intensity of UV radiation (Suárez Mascareño, A. et al., 2020) (Mascareño et al. 2020). This radiation is very important for biological systems, but excessive exposure can cause oxidative stress in cells and even damage to nucleic acids (Pourzand & Tyrrell, 1999) (Pourzand & Tyrrell 1999). Thus, this work aims to assess the survival rates of life as we know it in these environments.

To achieve this goal, we conducted experiments with the yeast *Rhodotorula dairenensis*. The sample was collected in Serra dos Cristais in Diamantina, Minas Gerais - Brazil (18.21408°S, 43.58771°W/1398 m), in May 2018. We performed three UV irradiation experiments with desiccated yeast. The first experiment was carried out with a tubular lamp that covers only the UVC region (254 nm). The second experiment was carried out with a continuous spectrum lamp that covers the entire UV range. The third experiment was conducted in the Space and Planetary Simulation Chamber (AstroCam) to simulate hypothetical conditions on the surface of Proxima b. In this chamber, we simulate an extreme atmosphere with 100% CO_2 and one that resembles that of primitive Earth (80% CO_2 and 20% N_2), with a pressure of 1000 mbar and with the continuous

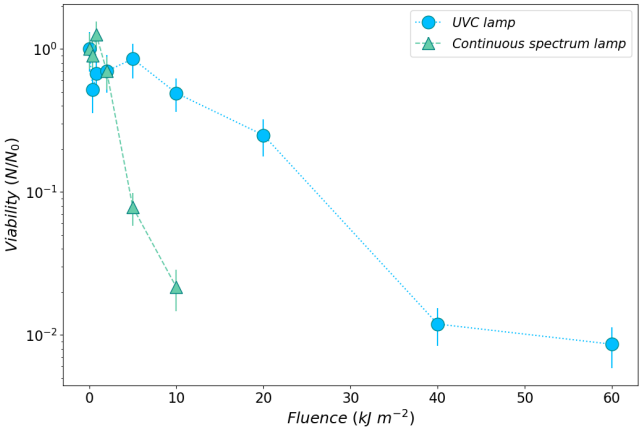

Figure 1. Survival curves for the experiments with *Rhodotorula dairenensis* desiccated. N_0 is the viable count of non-irradiated microorganisms, N is the viable count after irradiation. Experiments performed in triplicate.

spectrum lamp attached to the AstroCam. Our results for this last experiment were inconclusive due to the large error bars, so we will not discuss it here. Non-irradiated samples were used as control in the three experiments. We compared irradiated and control samples to estimate the survival rate of microorganisms.

The results of the experiments are presented in Figure 1. The results showed that irradiation with the continuous spectrum lamp (green line) was much more lethal than the tubular lamp (blue line). The UVA, UVB and UVC ranges cause different damages to cells and dealing with these stresses simultaneously could make their survival more challenging. Furthermore, we observed that there no viable microorganisms for a fluence of 10 kJ m^{-2} to the UV lamp and 60 kJ m^{-2} for the UVC lamp. Using the estimated flux of a typical UVC flare for Proxima b's orbit of 7 W m^{-2}

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(Welsh et al., 2007; Abrevaya et al., 2020) (Welsh et al. 2007; Abrevaya et al. 2020), those values would be reached in about 24m at 2.38h, respectively.

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Exploring protoplanetary disk evolution via MHD winds

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Keywords: *accretion, accretion discs, methods: numerical, MHD, planet-disk interactions, protoplanetary discs*

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We performed population synthesis of protoplanetary disks with MHD winds. We found that, for low viscosities, high torque values and strong disk winds best reproduce the accretion rates observed. We also found outward migration at ∼1au for masses $< 1M_{\oplus}$.

Recent results suggest that low viscosities could be the norm in protoplanetary disks, meaning that viscosity alone may not be the reason for their rapid dispersal. MHD winds act in disks threaded by a magnetic field, extracting mass and angular momentum, inducing accretion and reducing their lifetimes.

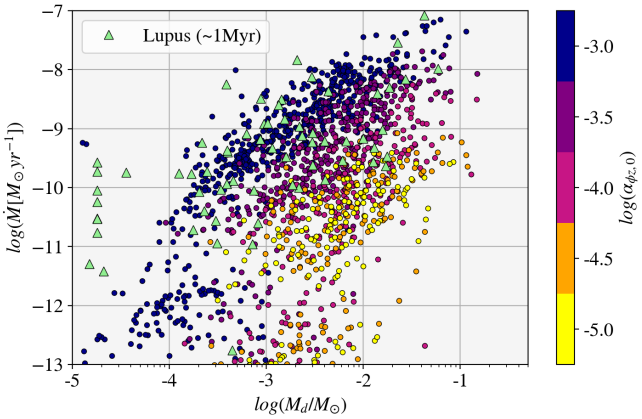

Figure 1. Accretion rates for the synthesis and Lupus cluster. Values for the DW torque strength are in colors.

Figure 1 shows accretion rates vs disk mass for our population synthesis, in comparison to observational data for the Lupus cluster. The synthesis consists of 5000 disks following empirical initial conditions for the disk and star parameters (Gómez, 2023), with $\alpha_{\phi z}$ between 10^{-5} and $10^{-3} M_{\star}/M_{\odot}$, in the Strong DW regime (Suzuki et al., 2016). We found that both viscosity and magnetic torque parameters need to be proportional to the stellar mass to account for the observed relation $\dot{M}_{acc} \propto M_{\star}^2$. We also implemented a star formation rate (Coleman & Haworth, 2022) and found it to be fundamental to reproduce the observed high accretion rates, especially in populations of ages >2Myr. MHD winds can also reproduce the observed dissipation time scales, resulting in characteristic lifetimes of ∼7Myr.

MHD winds affect the gas surface density profile, impacting the dynamical evolution of protoplanets. Outward migration is observed for protoplanets of masses $\lesssim 1M_{\oplus}$, at $r \sim$ 1au (figure 2). As proposed by Ogihara et al. (2018), this could explain the in-situ formation of close-in super-earths.

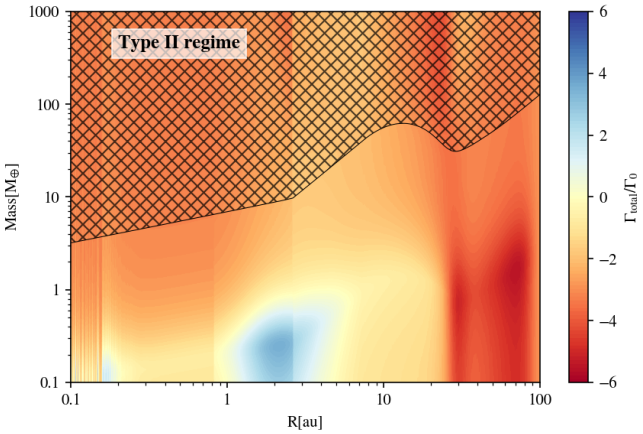

Figure 2. Migration map at 1Myr for a protoplanetary disk evolving via strong MHD winds with low $\alpha_{\phi z}$. Torque prescriptions are from Jiménez & Masset (2017) and type II regime zones from Crida et al. (2006).

Our results contrast with a recent study by Weder et al. (2023), who concluded that weak DW and strong torques are needed to reproduce the accretion rates, while strong DW cannot due to the rapid dispersal of the disk. The discrepancies could be due to our implementation of a star formation rate, and to the introduction of a proportionality of the magnetic torque parameter with the stellar mass.

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A density valley across stellar types

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The radius valley separating super-Earths from mini-Neptunes is a fundamental benchmark for theories of planet formation and evolution. Observations show that the location of the radius valley decreases with decreasing stellar mass and with increasing orbital period. Here, we build on our previous pebble-based formation model. Combined with photoevaporation after disc dispersal, it has allowed us to unveil the radius valley as a separator between rocky and water-worlds. In this study, we expand our model for a range of stellar masses spanning from 0.1 to 1.5 $M_\odot$. We find that the location of the radius valley is well described by a power-law in stellar mass as $R_{valley} = 1.8197\ M_\star^{0.14(+0.02/-0.01)}$, which is in excellent agreement with observations. Additionally, we note that the radius valley gets filled towards low stellar masses, particularly at 0.1 – 0.4 $M_\odot$. This is the result of orbital migration occurring at lower planet mass for less massive stars, which allows for low-mass water-worlds to reach the inner regions of the system, blurring the separation in mass (and size) between rocky and water-worlds. Furthermore, we find that for planetary equilibrium temperatures above 400 K, the water in the volatile layer exists fully in the form of steam, puffing the planet radius up (as compared to the radii of condensed-water worlds). As with Sun-like stars, we find that pebble accretion leaves its imprint on the overall exoplanet population as a depletion of planets with intermediate compositions (i.e. water mass fractions of $\sim$ 0–20%), carving an planet-depleted diagonal band in the mass-radius diagrams.

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Probing a laboratory asteroid model: Mechanical characterization under loading-unloading cycles

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This study examines the mechanical properties of asteroids on a laboratory scale, focusing on their relevance in space mission design, Earth collision hazard assessment, and understanding collisional processes. Following the NASA-DART mission, the effectiveness of deflection relies on factors like cratering events, momentum distribution in ejecta, and the propagation of impact-induced seismic waves within asteroids.

Our comprehensive laboratory-scale characterization of granular media in dynamic regimes offers a cost-effective alternative to in-situ measurements. Scaling experiments by approximately 300-fold simulates a Dimorphos-sized asteroid, revealing particle sizes of 5 to 50 cm as observed on the mission. Micro-gravity conditions on asteroids yield unique mechanical properties challenging to replicate on Earth. While non-realistic, our experiments aid in understanding seismic wave propagation's role in material expulsion within asteroids, contributing to the comprehension of active asteroids and enhancing our knowledge of asteroid interiors and boulder distribution.

We observe pressure waves with frequencies ranging from 200 to 500 Hz. Independently of the granular media, glass beads (artificial, spherical), sand (natural, irregular), and gravel (natural, irregular), the wavespeed follows a power-law relationship $v \propto p^{1/2}$, and indicates that the speed of seismic body waves is independent of the origin mechanism, suggesting safer wave-generating methods for low-gravity experiments instead of risky impact devices.

The equivalence between wave propagation from impacts and shaker-born perturbations is valuable for non-impacted testing to assess granular material properties in low-gravity conditions. With the upcoming Hera mission to the Didymos-Dimorphos system in 2027, aiming to study internal asteroid structure, our research lays a foundation for a deeper understanding of asteroid interiors and boulder distribution.

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The influence of stellar activity on the atmospheric properties of hot Jupiters

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Hot Jupiters are extremely irradiated gaseous exoplanets with orbital periods less than 10 days. Since they are exoplanets so close to their stars, it is reasonable to assume that there is a stellar influence on the atmosphere of these objects. It was previously shown in the literature that strong magnetic fields and high energy particles from the stellar chromosphere can affect hot Jupiters' atmospheres by causing mass losses and subsequently orbital decay. We analyze the hypothesis that hot Jupiters without thermal inversion orbit active stars, while hot Jupiters with inversion orbit inactive stars. We use a larger sample and updated data to reproduce two approaches from previous works that try to classify hot Jupiters according to their brightness temperatures in five infrared bands: 3.6 μm, 4.5 μm, 5.8 μm, 8.0 μm (Spitzer), J, H and Ks (2MASS). We also investigated the relationship between the incident radiation and the presence or absence of thermal inversions. We found a good correlation (Pearson r coefficient ≥ 0.6) between 5.8 μm and H brightness temperatures and the chromospheric activity index $\log R'_{HK}$. However, we did not find a clear separation between exoplanets with and without thermal inversion as a function of stellar activity. We also found that the most irradiated exoplanets have thermal inversion, while the least irradiated ones do not.

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Study of the dissipation times of gaseous disks in stellar populations

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Protoplanetary disks are the sites of planet formation. For this reason a correct modelling of protoplanetary disks is key to understanding planetary formation. In this work we present a disk population synthesis study aimed at reproducing the available observable properties of protoplanetary disks. We consider that disks evolve by viscous accretion and internal photoevaporation. The initial conditions, such as the masses and sizes of the discs, follow statistical distributions inferred from observations. We analyze the impact of stellar mass distributions and star formation rates on the time evolution of the fraction of stars with disks, and on the stellar mass accretion rates.

Our models show that, because massive stars dissipate their disks faster, the observed fraction of stars with disks in star-forming regions is dominated by disks around low-mass stars. The lifetime of protoplanetary discs has an uncertain distribution function, to calculate the average lifetime of disc on star formation region we consider that it follows a Log-normal distribution. From our models, we obtain a median disk lifetime of 4.2 My, showing very good agreement with observations.

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Variability of water vapor in the internal atmosphere of Mars associated with the solar activity cycle

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This work explores the intrincate relationship between Mars' atmospheric variations and dynamic solar activity patterns. We focus on periodic oscillations in H_2O vapor and the Pectinton solar flux index in the $\lambda = 10.7$ cm radio band, around the characteristic 11-year solar cycle. Periodic Mars activity was studied using data from Mars Express' SPICAM instrument spanning 2004-2018. The Lomb-Scargle Periodogram method was applied to analyze the power spectra of both signals around this period, calibrated using peaks associated with the seasonal Martian cycle. This method was validated by analyzing power spectra of chemical species abundances in Earth's atmosphere, obtained from the NRLMSISE 00 empirical model provided by the National Oceanic and Atmospheric Administration (NOAA). Model executions reproduced chemical abundance data for various atmospheric species (N_2, O_2, N, H_2, Ar, and He) at two reference heights (upper mesosphere and low ionosphere) over a 1961-2021 time span. Results suggest a connection between variability in H_2O vapor concentration in Mars' atmosphere and fluctuations in the Pectinton solar flux index. We propose the Lomb-Scargle Periodogram method as a heuristic for studying oscillatory activity in planetary atmospheres with non-uniformly sampled data. While our results provide valuable insights, further analysis, cross-referencing with data from different orbiters, is required to deepen our understanding of these findings in the fields of planetary climatology and atmospheric physics.

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Like a wrecking ball: understanding giant planets as the key to finding Earths

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Jupiter-like planets are the key to understanding Earth-like planets. Their presence can disrupt the orbits of inner habitable worlds, or deliver life-sustaining water. While the search for Earth-like planets orbiting nearby stars garners the most attention, it is critically important to understand the presence and properties of giant planets in those systems. In the next decade, three space missions will provide unprecedented new opportunities for understanding the nature of these Jupiter analogs: Gaia, the James Webb Space Telescope, and the Nancy Grace Roman Space Telescope. We aim to take advantage of the multi-messenger synergy of these observatories, in combination with Australia's unique Minerva-Australis telescope array, to obtain a complete picture of the nearest extrasolar planetary systems. Dozens of cold giant planets are known from radial-velocity planet searches. But their true masses remain unknown due to the limitations of the technique. In Data Releases 4 and 5 (2025/26) the Gaia space astrometry mission will deliver the critical measurements of 3-dimensional architecture for these planetary systems. Combined with the minimum masses obtained from radial velocities, we will obtain the true masses of those planets. Our Minerva-Australis observatory is fully dedicated to radial-velocity measurements; it is the only such facility in the Southern hemisphere. We will use these data to better characterise nearby Jupiter analogs for which true masses and orbital inclinations can be derived with forthcoming Gaia data. With detailed knowledge of the properties of those giant planets, we can model the extent to which those planets deliver water to inner Earth analogs via comet impacts. These Jupiter analogs will also be prime targets for direct imaging by JWST and Roman.

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Ejection experiment in soft granular media

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Asteroids have been shown to be composed of granular media, Tancredi et al. (2012) predicted the creation of dust clouds at low escaping velocities post-impact. Their study proposed that a layer of particles shocked from below could cause particles to ascend from the surface, a phenomenon known as the "cocoa effect".

Our research focuses on exploring particle velocities ejected from soft granular media, specifically rubber particles sieved into various sizes. The primary objective is to understand the behaviour of the cocoa effect at a laboratory scale, emphasizing the measurement of both height and velocity reached. Rubber serves as our chosen medium due to its notably slower wave velocity compared to harder media, facilitating movement capture through high-speed cameras. The experimental setup entails an acrylic prism filled with rubber, positioned atop a shaker with an attached accelerometer. We varied the shaker's pulse amplitude. Particle movement is recorded with a high-speed camera and analysed using Particle Image Velocimetry (PIV) and correlation techniques (phase tracking and time correlation).

Initial findings provide insights into the beginning of lofting and velocity variations within the column of material. Notably, the analysis reveals a correlation between the amplitude and slope of the observed phenomena. A larger amplitude corresponds to a steeper slope. To validate our observations, correlation tracking was employed, further substantiating that larger slopes indeed align with more substantial amplitudes. These results contribute to a comprehensive understanding of the dynamics involved in lofting within the soft granular medium, laying the groundwork for further investigation and refinement of our experimental approach.

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What is the frequency of meteorite falls? Is there a preferred day?

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Meteoroids are solid natural objects of a size roughly between 30 μm and 1 m moving in interplanetary space, that can reach the Earth upper atmosphere producing a noticeable phenomenon: a meteor. They might survive the meteor phase when passing through the atmosphere, and eventually reach the surface as meteorites. If recovered after observations of their passage they are called falls, whereas, if found by chance they are called finds. As of 20/11/2023 there are 1,218 recorded falls worldwide, with official names in the Meteoritical Bulletin Database. A subgroup among the falls are those that directly affect humans or their belongings (damaging falls). A meteoroid stream is a group of meteoroids with common orbits and origins (e.g., from the fragmentation of an asteroid), and is of great relevance because it might indicate the presence of a larger body, yet to be discovered. The aim of this work is to analyze the temporal distribution of meteorites, calculate how many meteorite falls per year, and how many of them are damaging. We determined if there is any preferred moment of the year with more meteorite falls. The frequency of falls per day over the entire Earth was calculated as a function of the day of the year and solar longitude; and compared with a Poisson process in order to look for dates with higher frequency than expected. From our analysis, an average rate of ∼7.82 falls and ∼1.72 damaging falls on urban Earth per year was calculated. Subsequently, ∼6,014 falls per year over the entire Earth's surface, and ∼1,777 falls per year over Earth's landmass were estimated from satellite data. No peaks in the distribution tail were observed, therefore, the presence of a meteoroid stream cannot be asserted. There is no particular day of the year with a higher fall rate, hence, it is likely that there are no highly populated meteoroid streams.

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Coorbital dynamics: a semi-analytical approach to study equilibrium points in resonant coorbital configurations under extreme inclination and/or eccentricity

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Co-orbital orbital dynamics is really important to understand some aspects of small body populations in our Solar System. The most studied case in the literature are Jupiter Trojans. Not all planets have known coorbitals. For example, Venus, Earth and Mars have confirmed ones but their stability has been a matter of some debate in the literature. There are several co-orbital motion types: tadpoles, horseshoes and quasi satellites. Remember that in the classic planar circular case we only have two tadpoles which librate around $\pm 60°$, these are called Trojans and are located in usually called L4 and L5 equilibrium points. It is important to notice that when the eccentricity or inclination of the secondary body grows those points change their position. This semi-analytical approach can be used to study any resonance such as 1:1 in this case. It provides a numerically integrated Hamiltonian and equilibrium points, as well as resonance widths and periods of librations. The advantage of using this theory is that we do not have restrictions in eccentricity nor inclination except for almost circular orbits where the hypothesis of the model fails. Our objective is to test the model under extreme conditions. Using it, we have mapped the location of equilibrium points for high eccentric and/or inclination orbits and searched for possible known asteroids in the NASA Horizons catalog that match this type of orbits. Furthermore, some problems can be modeled with this work such as pollution in white dwarf spectra. It has been proposed that post main sequence evolved small body population falling into the star due to resonant perturbations in high eccentric orbits could explain this. Also, we can apply this theory to study systems with two co-orbital planets such as the recent evidence for exoplanet system PDS 70 could indicate.

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Search for cometary activity in transitional objects using archival images and new observations: preliminary results

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We present the monitoring of a set of Asteroids in Cometary Orbits (ACOs) and Activated Asteroids (AAs), which are part of transitional objects: bodies that do not fully fit the traditional categories of asteroids and comets. Using archival images from the Dark Energy Survey (results not revised by the Collaboration yet), ESO's Very Large Telescope, and Instituto de Astrofísica de Canarias, alongside recent data from Observatório Astronômico do Sertão de Itaparica, we employ two distinct techniques to detect signs of cometary activity: i) the comparison of the surface brightness profile of the objects with those of field stars, ii) the study of the reduced magnitude vs. the heliocentric distance in search of increases in brightness, using data from the Minor Planet Center, and those obtained in the observations. We analyze the profiles of 133 ACOs and seven AAs and the reduced magnitudes of all the ACOs (705). Eleven ACOs presented a deviation in the surface brightness profile and/or in the reduced magnitude. We found a very small percentage of objects with signs of low-level activity, which would rule out a slow transition from active to inert. Four AAs were active in the images, three being coincident with the existing reports, while in the case of P/2015 X_6, we extended the activity period in 19 days. We could observe that the episodes of activity are very restricted in time and do not always occur in the same region of the orbit.

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Tidal evolution in dwarf planets systems as an application of the creep model

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To date, there are five confirmed dwarf planets, four of which are located in the trans-Neptunian region, namely: Pluto, Eris, Haumea, and Makemake. All four have natural satellites. It is well known that Pluto-Charon's rotations are synchronized with the orbital motions. Eris and Dysnomia also have their rotational and orbital periods synchronized, respectively. This synchronous state is a natural consequence of tidal interaction between the dwarf planet and its main satellite. In this work, we propose to investigate the orbital evolution of the tides in Pluto-Charon and Eris-Dysnomia systems using the creep model, where the main parameter is the viscosity attributed to the deformed body. Regarding the action of the tides on both bodies, we integrated the equations for the mean variations of semi-major axis, eccentricity, and rotation velocity over Gyr timescales, to investigate when and how the system could have entered into synchronous motion. In addition, based on the equations of the creep model, we performed a parameter space analysis to obtain the most influential parameter on the orbital evolution of dwarf planets and their satellites.

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Reviewing cometary-like asteroids in view of the DART experiment

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Several objects in asteroidal orbits have presented comaes and tails like the ones presented by comets. There are at present (12/2023) 46 objects that have presented, at least for a brief period, this cometary-like appearance. These objects are generally coined "Active Asteroids", implicitly implying that some kind of on-going endogenous or exogenous active process is the mechanism that produce the long-lasting tails. Nevertheless, what we observe is that those asteroids are temporally dressed as comets. Several hypotheses have been proposed to explain the "activity" of these objects.

Lessons from DART: The NASA-DART experiment gave us an opportunity to review our knowledge of this population. Following the impact of the space probe against asteroid Dimorphos on September 26, 2022, several thousand tons of material were ejected at a wide range of velocities. Tancredi et al. (2023) dubbed the DART experiment as the creation of the first artificial "Active Asteroid". They proposed that the production of a large amount of low-speed ejected material could be described by the "cocoa effect": the lofting of small particles from the top of a dust layer by shaking the ground. The seismic shaking, combined with the "cocoa effect," may lead to the ejection of particles from a significant portion of the affected hemisphere. They predicted a brightness increase due to a slowly moving dust cloud, the obscuration of Dimorphos' surface by this cloud, and the generation of a long-lasting tail; which were confirmed by the close-by observations of LICIACube, as well as long-range tracking from HST and the ground. By July 2023, over 250 days after impact, the tail was still visible.

Based on these results, we reviewed the relevance of the different mechanism proposed to explain the appearance of the population of asteroids temporally dressed as comets.

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Qualitative analysis of the dynamical evolution of planetary systems

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Discoveries of extrasolar planetary systems have shown that the configuration of our Solar System is an exception to the rule given the number of systems with high relative inclinations, large eccentricities and high mass planets in orbits with periods of hours. Due to these peculiar characteristics, our goal is to understand the processes that led planetary systems to acquire such characteristics, through mutual gravitational interaction and with the proto-planetary disk. To verify the quality of the observational data and the stability of the planetary systems in periods of at least 1 Myr, we use the concepts of Hill Stability (Marchal & Bozis (1982) and Gladman (1993)) that consider the configuration of the systems in terms of total energy and orbital angular momentum; to evaluate their secular movements we work with the construction of Representative Plans that bring with them information of the long-period behavior of the system, based only on the mass ratio of the planets and the ratio of their semi-major axes; To analyze the temporal evolution, we use the theory of semi-analytical perturbation (Michtchenko & Malhotra, 2004) that allows us to explore systems of high eccentricities by not working with series expansions of the Disturbing Function. We work with models that simulate the process of planetary migration (Michtchenko & Rodríguez, 2011), which change the orbital elements in a forced way, seeking to relate the migration trajectories with known processes, interaction of the planet with proto planetary disk, accretion of matter and tidal effects. Using the stability criteria, we selected some planetary systems to start the analysis and, after verifying their secular behavior, we started the simulations of migratory processes to understand through which configurations the system passed until arriving in the current state, considering only the variation of the total energy of the system and the orbital angular momentum.

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A local approach of planetesimal fragmentation applied to planet formation

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One of the challenges in planetary formation models is, including the main physical phenomena in that process, to explain the diverse architectures of planetary systems observed to date. The modelling of collisions and planetesimal fragmentation is key to reproducing planetary formation and evolution correctly. Our previous works show that the inclusion of a detailed model of planetesimal fragmentation, considering different compositions and relative velocities of planetesimals, may inhibit or favour the formation of giant planet cores, drastically changing the final planetary system architectures. However, in global planetary formation models, the detailed modelling of these processes is extremely expensive from a computational point of view. Generally, these models include the planetesimal fragmentation process locally. In this work, we study a local approximation of this process that simplifies the phenomenon numerically, significantly reducing the computing time required for our simulations. We compare these results to our detailed model of planetesimal fragmentation applied to giant planet formation and contrast it with other local approximations in the literature to determine its validity.

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The AGE-PRO ALMA Survey: A glimpse into the gas evolution in protoplanetary disk

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The fundamental question of how the gas and solids in protoplanetary disks evolve with time remains unanswered. However, the ongoing ALMA Large Program AGE-PRO ("ALMA survey of Gas Evolution in PROtoplanetary disks") was designed to answer this question for the gas component. AGE-PRO will trace the evolution of gas disk mass and size throughout the lifetime of disks, using a well-defined sample of 30 disks between 0.1 and 10 million years old. By studying a large sample of disks at different ages, AGE-PRO will be able to identify the key factors that drive the evolution of gas disks and to better understand how these disks ultimately give rise to planets.

Here, we present the preliminary analysis on Upper Scorpius and Ophiuchus, the oldest and youngest regions in our sample, respectively. For Upper Scorpius we have imaged gas and continuum emission, and generated disk-integrated line fluxes and radial intensity profiles for all lines and for the continuum, in all 10 disks selected. ^{12}CO emission is ubiquitous across the entire sample, with detection in all observed sources. In contrast, transitions of its heavier isotopologues, ^{13}CO (2-1), and C^{18}O (2-1), exhibit lower detection rates of 60% and 40%, respectively.

Additionally, we have analyzed the young Ophiuchus star forming region to examine the nature of the gas rotation with CO isotopologues. We are deriving rotational profiles from the PV diagrams and the size of Keplerian disks for Class I/FS sources.

These results will establish a foundation for understanding the global structure and evolution of protoplanetary disks. This will provide essential context for future in-depth studies of planet formation processes in disks.

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Rotational period determination of fortuitous asteroids

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In this work we present the results of the photometric analysis of 11 asteroids whose rotation period has not been estimated and which we consider to be fortuitous as they were not the main objective of the photometric observations. They were present in the same field of view as the asteroid of study and showed sufficient brightness for photometric analysis. The images analyzed correspond to 23 nights in 2022, and were obtained from the National Astronomical Observatory of San Pedro Mártir, using the 84 cm telescope. Image processing, aperture photometry, and differential photometry were performed to calculate light curves. Subsequently, a search for the value of the corresponding rotation period was carried out using Fourier series analysis, employing a computational program that performs a rotation curve fitting. The complete data is available in: here.

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Evaluation of the AUTOBOL algorithm withh a sample of events detected by the BOCOSUR Network in Uruguay

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BOCOSUR is a network of 20 stations deployed in Uruguay to detect fireballs (meteors brighter than Venus). Autobol is a machine learning-based algorithm that is capable of processing images and detecting events from a series of videos. The learning process of the algorithm begins with a manual classification of videos as with and without fireballs, this is essential because by choosing good candidates for videos with fireballs the learning is more specific. RANSAC "RANdom SAmple Consensus" is responsible for estimating the parameters of a mathematical model in Autobol.

Since 2019 we have deployed a network of stations with allsky cameras for the detection of bright meteors (fireballs). By October 2021, 6 stations were installed in the south of Uruguay, in what made up the first stage of the Red de Detección de Bólidos del Cono Sur (BOCOSUR). The stations run an application developed by our group (see Caldas et al. in this conference), which detects any change in brightness in consecutive frames. Therefore, a classification should be made between videos with and with out fireballs. In 2022, a group of Electrical Engineering students (Ballestrino et al. 2022) developed an algorithm based on machine learning for the automatic classification of the videos, using the classification we had done as a training base. To train the Autobol package, we used the manual classification of $\sim$ 8000 videos, where 363 of them have fireballs. In this poster we present the results of applying these predictive classification models to a database of over 250,000 videos. We present statistics on the performance of the network and the classification algorithm.

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Experimental simulation of a solar UV environment on mars and its effects on germination and photosynthetic pigment content of Chenopodium Quinoa

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Mars exploration has become a human goal in recent years, as the possibility of colonizing this planet opens up space for research and innovation in fields such as astronomy, astrophysics, astrobiology, among others. International agencies have directed their efforts to conduct various reconnaissance missions to Mars, with the aim of not only preparing for future human existence on the red planet but also ensuring food sustainability. Considering the above, this work has the main goal of simulating an experimental environment that replicates the environmental conditions of Mars related solely to solar ultraviolet radiation levels and establishing their effect on the germination and photosynthetic pigment content of *Chenopodium quinoa*. We focused on establishing the effect of these conditions on the germination and photosynthetic pigment content of *Chenopodium quinoa*, in order to make a pilot study for future colonization and subsistence on the planet. It was found that UV radiation stimulates the emergence of seeds from different *Chenopodium quinoa* materials, acting as a directed photomorphogenic signal. Specifically, at shorter wavelengths, the germination percentage was higher compared to normal conditions. Something very similar happened with the plants, where treatments with UV resulted in notable increases in the concentration of total chlorophyll at short wavelengths, showing an "automatic" increase in both materials. Further study of these behaviors in more extended experiments and with materials from other plant species would be worthwhile.

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To use or not to use model stellar spectra to study integrated stellar populations?

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Keywords: *stars: atmospheres*

Abstract

Spectral stellar libraries are essential to stellar population models. They can be empirical or theoretical, each with its own advantages and disadvantages. Here, we discuss the results obtained by studying the impact of model stellar spectra on stellar population models and make an application to integrate light of globular clusters. We conclude that stellar population models built with model stellar spectra rival and often outperform models based on empirical spectra.

Resumen

Las librerías de espectros estelares son esenciales para los modelos de poblaciones estelares. Estas pueden ser empíricas o teóricas, cada una con sus propias ventajas y desventajas. Aquí discutimos los resultados obtenidos al estudiar el impacto de los espectros estelares modelados en los modelos de poblaciones estelares y hacemos una aplicación a la luz integrada de cúmulos globulares. Concluimos que los modelos de poblaciones estelares construidos con espectros estelares modelados compiten con, y a menudo superan, a los modelos basados en espectros empíricos.

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1. Introduction

The field of stellar population studies sits at the frontier between stellar and extragalactic astrophysics. It uses our knowledge of the evolution of stars and gas to predict the light evolution of galaxies (Tinsley, 1980). The field was born with Baade (1944), who observed stars in M31 and satellites, noting similarities with Galactic stellar systems. When individual stars cannot be resolved (the vast majority of the universe), we need to use integrated light models to simulate the observables of stellar populations (Bruzual & Charlot, 2003, e.g.).

The starlight, coming from libraries of stellar spectra, is a central ingredient. While some models eschew isochrones and initial mass function assumptions (e.g. Martins et al., 2019), the selection of a stellar flux library remains unavoidable. These libraries comprise homogeneous compilations of stellar spectra, each tagged with characteristics like effective temperature, surface gravities, and abundances.

The literature features over a hundred such libraries, which are also used for automatic determinations of stellar parameters (e.g. Dias et al., 2015), studies of exoplanets via radial velocities measurements (e.g. Spring et al., 2022), and photometric calibration in surveys (Almeida-Fernandes et al., 2022).

2. A problem and an experiment

A spectral stellar library can be empirical (based on observations, e.g. Sánchez-Blázquez et al., 2006) or theoretical (relying on atmosphere models and radiative transfer codes; e.g. Coelho, 2014).

Empirical libraries have relatively sparse coverage of the Hertzsprung-Russell (HR) diagram, constrained by the star formation and chemical histories of the observed stars. This limitation prompted the use of stellar population models based solely on theoretical stellar spectra in some cases (e.g. Leitherer et al., 1999; Coelho et al., 2007). Theoretical libraries offer optimal HR diagram coverage but may contain inaccuracies in certain spectral regions or parameter space due to opacities or implemented physics (e.g. Martins & Coelho, 2007).

Stellar population models will inherit errors and uncertainties from the chosen library. In the absence of a library with both optimal coverage of stellar parameters and excellent reproduction of spectral line profiles, which should we favour, better parameter coverage (model stellar spectra) or superior spectra on a star-by-star basis (empirical stellar spectra)?

The work by Coelho et al. (2020, hereafter CBC20) attempts to answer that question. The authors modelled Simple Stellar Population (SSP) models with fixed initial mass function and isochrones and three different stellar flux libraries: the empirical MILES (Sánchez-Blázquez et al., 2006), the theoretical from Coelho (2014) and a synthetic library with the same (sparser) coverage of the HR as the empirical library. They isolate two effects: the "coverage effect" which pertains to the impact of a sparse HR diagram coverage on SSPs, and the "synthetic effect", which relates to uncertainties in model stellar spectra.

3. Discussion

CBC20 investigates the impact of different stellar libraries on SSP model predictions and on inferred parameters of a sample of bulges. However, stellar clusters serve as better benchmarks, as we can compare the integrated light parameters with ages derived from isochrone fitting and high-resolution metallicities obtained for resolved stars

Gonçalves et al. (2020, hereafter, G20) analysed integrated spectra of stellar clusters (Usher et al., 2017) using the spectral fitting code STARLIGHT (Cid Fernandes et al., 2005) and models by Vazdekis et al. (2015). The integrated light parameters reproduced the reference values from the literature reasonably well for high metallicity objects. However, for low-metallicity clusters, ages were significantly underestimated (see their Fig. 11), a phenomenon traditionally attributed to blue horizontal branch stars.

Here we replicate the analysis conducted by G20 using the SSP models provided by CBC20 (figure 1). The top panel, akin to Fig 11 in G20, still exhibits a notable age discrepancy. Yet, the results based on model stellar spectra (orange, with optimal coverage of the HR) are about 2 Gyr closer to the literature values than the ones based on an empirical library (blue, sparser coverage). Concerning metallicities (bottom panel), those obtained from SSPs based on a theoretical library are, on average, closer to the literature values than those obtained from SSPs based on an empirical library (Δ[Fe/H] = 0.02 vs. 0.20).

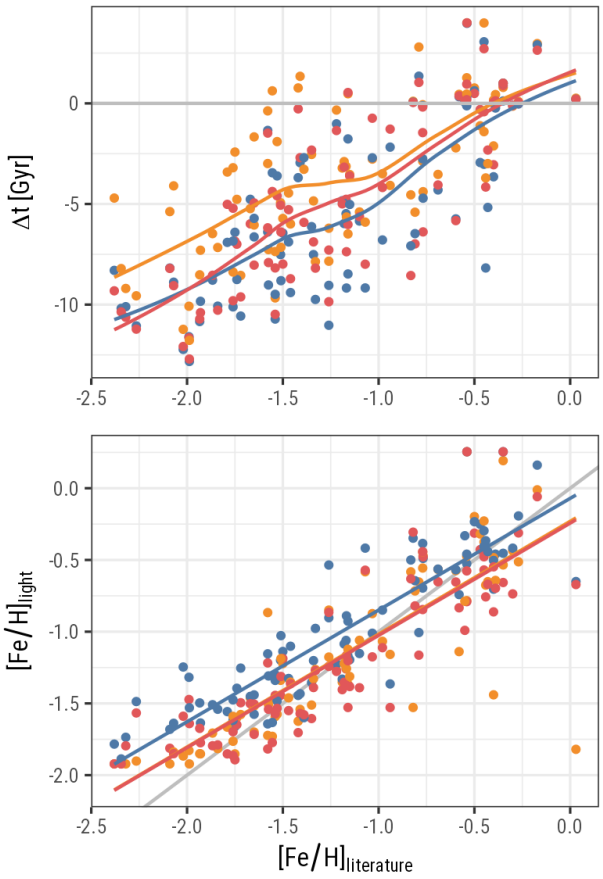

Figure 1. Results are shown comparing the integrated light properties of galactic globular clusters, inferred from spectral fitting. The top panel shows the difference in age between the integrated light and those derived from isochrones (Δt) as a function of iron abundance [Fe/H]. The bottom panel depicts integrated light [Fe/H] versus abundances derived from high-resolution spectral analysis. Orange symbols are results obtained from SSP models based on theoretical libraries, blue symbols correspond to models based on empirical libraries, and red symbols correspond to models based on theoretical libraries with a coverage of the HR equal to that of the empirical library. Lines are fitted to the data for visualization purposes, with a LOESS fit in the top panel and a linear fit in the bottom panel.

4. Conclusions

The conventional wisdom has held that SSPs based on model stellar spectra are valuable for systems with chemical patterns differing from the solar neighbourhood and very young systems, while models based on empirical stellar spectra should be favoured otherwise. However, the findings of CBC20 and those presented here paint a different picture: modern theoretical libraries not only compete with but, in some instances, outperform models based on empirical libraries (see as well Martins et al., 2019). Through the study of the integrated light of stellar clusters, we note that the coverage effect can explain up to 25% of the "blue-light excess" of metal-poor star clusters, thus mimicking the presence of blue horizontal branch stars. Additionally, model stars, on average, better reproduce iron abundances from literature. Further work is underway, including stellar clusters from the Magellanic Clouds (Asad, Coelho et al., in preparation).

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The early stages of stellar cluster formation (Invited contribution)

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Keywords: *ISM: magnetic fields, stars: formation*

Abstract

How stellar clusters form and what determines their richness or stellar density are long-standing questions, intimately related to the fragmentation properties of molecular clouds. We present a summary of observational campaigns carried out by our group, aimed at disentangling which properties, if any, finally control the fragmentation process in the dense parts of molecular clouds, from 0.2 pc to 1000 au scales. We show a tentative correlation between the fragmentation level and the mass-to-magnetic flux ratio, as predicted by theoretical and numerical works, along with a strong correlation with density. Finally, we mention future research lines that involve the new generation of interferometers such as the next-generation Very Large Array.

Resumen

La formación de los cúmulos estelares y los procesos que determinan su riqueza o densidad estelar son preguntas abiertas desde hace mucho tiempo, íntimamente relacionadas con la fragmentación de las nubes moleculares. Se presenta un resumen de las campañas observacionales llevadas a cabo en nuestro grupo con el objetivo de desentrañar qué propiedad, si es que alguna, controla el proceso de fragmentación de las partes más densas de las nubes moleculares, desde escalas de 0.2 pc a escalas de 1000 au. Se presenta una correlación tentativa entre el nivel de fragmentación y el cociente masa-flujo magnético, tal como han predicho numerosos trabajos teóricos y numéricos, además de una correlación fuerte con la densidad. Finalmente, se indican líneas de investigación futuras que involucran las nuevas generaciones de interferómetros como el next-generation Very Large Array.

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1. Introduction

The formation of stellar clusters is an essential and highly evolving topic in Astrophysics. Although this topic has a vital role in Galaxy evolution, the details on how this process takes place are still poorly constrained, in part because it involves a number of physical phenomena. It is widely accepted that stellar clusters form in dense, hierarchically structured and highly dynamic gas clouds (Fig. 1-top), where filamentary structures feed the dense massive cores, usually arranged in a hub-filament system (Fig. 1-bottom-left). As the cloud, and filaments within it, evolve, fragmentation takes place producing the seeds of the future nascent cluster (Fig. 1-bottom-mid), typically located at the hub or the deepest potential well of the cloud (Fig. 1-bottom-right; e.g., Krause et al., 2020). Thus, the process of fragmentation of a molecular cloud is essential to understanding the formation of stellar clusters. This fragmentation process could be controlled by a number of factors such as the density and temperature structure, turbulence, initial angular momentum, stellar feedback, and magnetic fields (see references in Palau et al., 2021). Disentangling which of these factors, if any, dominates

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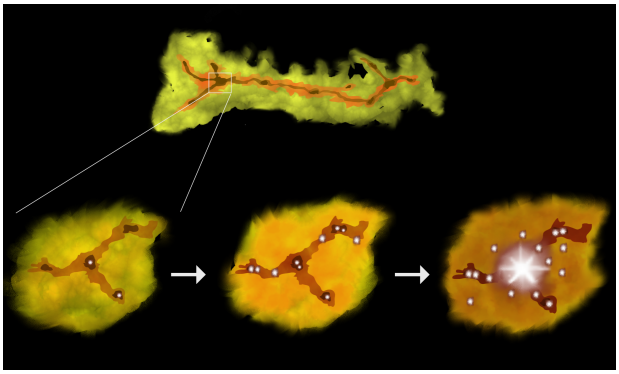

Figure 1. Sketch describing how stellar clusters form (see main text in Sec. 1).

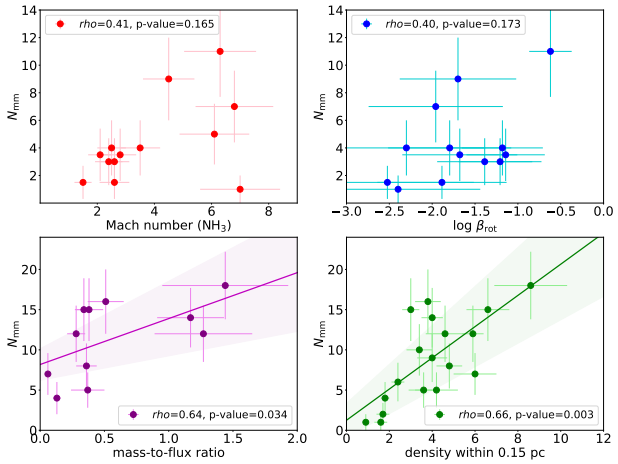

Figure 2. Summary of correlations between the fragmentation level, N_{mm}, and several parameters of the parental structures (Palau et al., 2014, 2015, 2021).

the fragmentation process is a big challenge from an observational point of view.

2. Observations of the different factors influencing the fragmentation level

In order to study the different factors influencing the fragmentation process, several observational campaigns were conducted from 2010 to 2020. The objects under study were selected to be massive dense cores (masses 100–1000 $M_\odot$, and sizes of 0.1–0.5 pc) with limited stellar feedback, which are supposed to be the cradles of the future stellar clusters. Two main samples were built for this purpose. To characterize their fragmentation level, we studied these samples using millimeter interferometers at subarcsecond angular resolution (yielding spatial resolutions of about 1000 au at 2 kpc). Regarding the characterization of the massive dense cores, single-dish observations of millimeter/submillimeter continuum emission and line emission were performed. In addition, Very Large Array (VLA) NH_3 (1,1) observations were gathered for all the regions of the sample. A first sample with all these data is presented in Palau et al. (2013, 2014, 2015). From these works, a study of the fragmentation level, N_{mm}, vs. several parameters was performed. N_{mm} is estimated by counting the number of millimeter compact sources within the same field of view of 0.1 pc for all the regions. The top panels of Fig. 2 show the results for N_{mm} vs. the Mach number and N_{mm} vs. the rotational-to-gravitational energy ratio, β_{rot}. In these two cases, the Spearman's rank correlation coefficient ρ is around 0.4, and the p value is > 0.16, indicating that there is no correlation.

The second sample was built by requiring that Submillimeter Array (SMA) polarization data were available (mainly from Zhang et al., 2014, and the SMA archive). The data were carefully analyzed in a uniform way and no correlation was found for N_{mm} vs. mass-to-magnetic flux ratio *unless* the velocity field was treated as the magnetic field, i.e., separating the large-scale component from the small-scale component by means of the two-point-correlation function. When doing this, the result of the bottom-left panel of Fig. 2 was found, revealing a tentative correlation ($\rho \sim 0.64$, and $p \sim 0.034$) consistent with numerical and theoretical works: the higher the mass-to-flux ratio, the higher the fragmentation level because the magnetic field is offering less support against gravity. It is important to stress that if the velocity field is not separated into a large-scale and a small-scale component, no correlation is found, consistent with the analysis performed in other works such as Beuther et al. (2024). Finally, the bottom-right panel of Fig. 2 shows a strong correlation ($\rho \sim 0.66$, and $p \sim 0.0035$) of N_{mm} with the density averaged within the common field of view of the second sample, of 0.15 pc. Again it is important to note that in order to recover such a strong correlation, the density needs to be calculated within the field of view where fragmentation is assessed, and that there is no strong correlation with the density *structure* or the density power-law index of the parental core as found also by Beuther et al. (2024).

In summary, when the samples are studied carefully in a uniform way, a tentative correlation of N_{mm} with the mass-to-flux ratio and a strong correlation with the density are revealed, suggesting that these factors could potentially be important in the fragmentation process. Future promising research lines focus on the chemical content of the cluster members, such as the detection rate of hot corinos in the nascent cluster and the possible dynamic link between the different cluster members. In this sense, the ngVLA will be of pivotal importance to image the details of the gas linking large-scale structures of the parental core with the compact sources of the cluster, allowing us to further understand this fascinating process of stellar cluster formation.

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Towards a better determination of stellar parameters in the pre-main sequence phase

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Keywords: *stars: abundances, stars: pre-main-sequence, techniques: spectroscopic*

Abstract

Large scale spectroscopic surveys are providing, for the first time, robust samples of young stars spectra, which may allow us to understand the origin of current Galactic disk populations and to increase the precision with which we study the pre-main sequence stage of stellar evolution.

Resumen

Los sondeos masivos de espectroscopía proveen, por vez primera, muestras robustas de espectros de estrellas jóvenes, que podrían ayudarnos a entender el origen de las poblaciones actuales en el disco Galáctico, asi como mejorar la precisión con la cual entendemos la fase de pre-secuencia principal de la evolución estelar.

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In the last 10 years, large-scale multi-object fiber spectroscopic surveys (e.g. Gaia-ESO, GALAH, SDSS APOGEE-2), combined with Gaia parameters have allowed us to study the detailed properties of stellar populations. Young stars in our Galaxy allow us to understand the origin population of the galactic disk. Was it similar to what we currently find in nearby star-forming regions? More important: Can these databases help us to characterize the Pre-Main Sequence (PMS) stage of stellar evolution? How robust are the samples we need to allocate the precision to understand parameter variations in terms of complex physical processes like accretion, variability and others?

SDSS APOGEE spectrographs (R∼22500, $1.5 < \lambda < 1.7$ μm) provide radial velocities near 0.1 km/s precision, can penetrate through dusty regions, and allow to map relatively crowded population using multiple visit schemes. The SDSS Milky Way Mapper (MWM) survey now also includes BOSS R∼3000 $0.3 < \lambda < 0.9$ μm optical observations, which improve spectral type classification and provide stronger accretion features. By SDSS DR17-18, a number of important star-forming regions and young cluster regions were explored, yielding a few thousand of YSO spectra Román-Zúñiga et al. (2023). The MWM will increase the sample by one order of magnitude in the next few years.

State of the art software makes use of powerful neural networks (Sprague et al., 2022) to determine the best sets of spectral parameters (T_{eff}, $\log g$, υ_{rot}, υ_R, [Fe/H]) using spectral label compilations. While this approach is powerful, the direct comparison of spectra and synthetic models allows more precision, specially towards the determination of detailed chemical abundances and the characterization of effects like extinction and circumstellar veiling.

Our code `TONALLI` (Adame et al., 2024) uses the Asexual Genetic Algorithm of Cantó et al. (2009) to locate and interpolate the best possible model from a grid that provides a set of parameters from an APOGEE spectra. Our approach includes a machine learning routine to assign spectro-photometric priors from PMS evolutionary models, which reduces model dependencies, especially for $\log g$.

Our work with `TONALLI` is currently allowing us to determine chemical abundances in young stars of the solar neighborhood. Our calibration sample is composed of main sequence stars within 100 pc from the Sun (López-Valdivia et al., 2024). Our main goal is to be able to produce a catalog of chemical abundances in nearby (up to 2 kpc from the Sun) star-forming regions and understand how they deviate (or not) from Solar abundances.

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Impact of evolutionary status on cool giant stellar activity levels

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Keywords: *Hertzsprung–Russell and colour–magnitude diagrams, stars: activity, stars: evolution, stars: horizontal Branch, stars: late-type*

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Since the beginning of the past century, ideas regarding spectral features as indicators of stellar activity began to settle down, spurred by the UV emission taking place in the middle of Ca II H and K absorption lines observed in several stars, which resembles the behavior of magnetically disturbed solar regions (Eberhard & Schwarzschild, 1913). Such a feature became standard chromospheric activity proxy after the introduction of the *S-index* in the dedicated long-term monitoring program at Mt. Wilson (Duncan et al., 1991), and its wide usage has made it possible to find activity prevalence all across the HR diagram i.e. in all stages of evolution. Of particular relevance is the central helium burning phase in intermediate-mass stars, as it serves as a relatively stable transitional stage between the Main Sequence and the Asymptotic Giant Branch, and hence as the ideal place to explore the demeanor of activity aiming to explain the decidedly heterogeneous set of observations of both MS and AGB groups.

In this work, the physical parameters of a sample composed of 28 late-type stars (spectral types G and K) were determined using recent parallaxes from Gaia DR3 together with analysis of the medium-resolution spectra (R approximately 21000) obtained in a dedicated observing program managed in the TIGRE, a robotic telescope in central Mexico (Schmitt et al., 2014).

Through comparisons with well-tested evolutionary tracks computed with the Eggleton code in its updated version (Pols et al., 1998), mass values and stages of evolution were also derived, which in turn were put into perspective together with measurements of the S-index indicator of chromospheric magnetic activity.

Four of the stars in the sample belong to the open cluster M41, so their coeval nature has made it possible to impose additional constraints to model their evolution, and thanks to this, the permanence of the activity exhibited during the relatively stable central helium-burning stage has been explored in good detail, whereas the non-cluster stars offer an insight into peripheral stages of evolution.

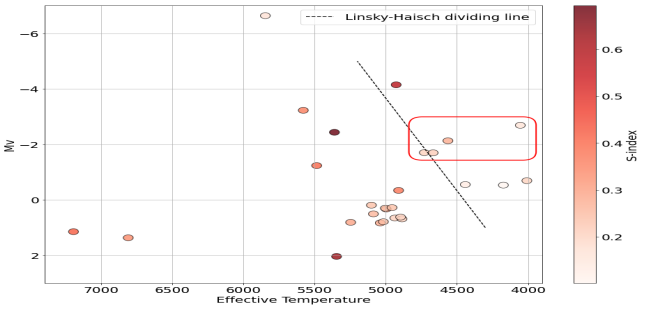

Figure 1. The Linsky-Haisch Dividing Line location in the HR diagram alongside the stellar sample. M41 giants are framed in red.

Evidence points to a correlation between the state of evolutionary advancement within the horizontal branch and a sustained decline in activity, analogous to what has long been known to occur among cool main-sequence stars, and just as it was discovered to occur in the four Hyades K giants (Schröder et al., 2020). Moreover, the presented measurements mirror the behavior of more energetic activity tracers such as coronal X-ray emission depicted at both sides of the Lisky-Haisch dividing line (Fig. 1), remarking the key role of these particular late stages of evolution in activity development and progression.

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Lithium depletion in solar analogs: age, mass and planet effects

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Keywords: *stars: abundances, stars: evolution, stars: late-type, stars: solar-type*

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The goal of this work is to evaluate the correlation between Li abundance, age, and mass. Our joint analysis of 151 solar-type stars confirms the strong Li abundance-age correlation reported by other works. Mass and convective mass also seem to be connected with Li abundance but with lower significance. We have found a link between the presence of planets and low Li abundances in a sample of 192 stars with a high significance.

Lithium (Li) is an important element for stellar astrophysics because it is destroyed at a temperature of 2.5×10^6 K, which is easily reached in the interior of stars. The base of the convective zone of main-sequence solar-type stars does not reach a temperature above $\sim 2 \times 10^6$ K. Thus, since the standard stellar model does not consider any mixing processes besides convection, the Li abundance of a single solar-type star should not change as the star evolves along the main sequence. However, these stars present a decay of Li abundance with stellar age (Carlos et al., 2019), indicating the existence of non-standard transport mechanisms. Many possible mechanisms were invoked, but there is still no model capable of explaining every characteristic regarding Li abundance.

Our sample consisted of 74 nearby solar twins and analogs (published in Rathsam et al., 2023) plus 79 solar twins from Carlos et al. (2019). The stars have solar metallicity (within $\pm$ 0.15 dex) and their mass ranges between 0.85 and 1.10 $M_\odot$.

We employed HARPS spectra (R $\simeq$ 115 000; 270 $\leq$ SNR $\leq$ 1000) taken from ESO's public database. To find the atmospheric parameters, we measured Fe lines via the line-by-line differential method and applied the spectroscopic equilibrium with the code q^2 (Ramírez et al., 2014). The masses and ages were found via a probability distribution from q^2. The Li abundances were determined via spectral synthesis of the 6707.8 Å line with the code MOOG. Convective masses were found via interpolation based on theoretical values from Spada et al. (2017).

Our results show a strong trend of lower A(Li) with larger age but with a much larger scatter than in the sample of solar twins from Carlos et al. (2019) (Fig. 2 in Rathsam et al. 2023). In particular, low-mass stars appear more Li-depleted. To evaluate the effect of age in A(Li) for solar twins, we selected stars with masses between 0.98 and 1.02 $M_\odot$ and performed an orthogonal distance regression. The resulting fit shows a strong correlation, with a significance of 14-σ.

The stars in our sample show lower A(Li) for lower mass or higher convective mass, which is consistent with what is predicted since low-mass stars present deeper convective envelopes and are expected to burn more Li. To quantify the influence those parameters on A(Li), we fitted the residuals of the relation found for solar twins as a function of mass and (convective mass)/mass for our entire dataset. The results show that while age is still the most important parameter governing A(Li), mass and convective mass also play a role (with a significance of 2-σ for mass and 5-σ for conv. mass/mass).

Finally, to test whether planet-host stars are more Li-depleted (which could be related to the process of formation of planetary systems, Meléndez et al. 2009), we included in our sample the stars from Martos et al. (2023). Out of 192 stars, 36 had confirmed orbiting planets. We then compared the Li abundance of planet hosts with the average or median abundance of non-hosts "twin" stars and found that planet-hosts appear more Li depleted by $\sim$ 0.2 dex, with a significance above 99% for our results (estimated via a t-test).

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A TESS survey of flare activity and stellar rotation of Young Stellar Objects (YSO) in the Taurus region

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Keywords: *stars: flare, stars: pre-main-sequence*

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In this work, we present the most numerous survey of flare detection on 346 YSOs in the Taurus region, which represents ∼67% of the low mass members cataloged by Esplin & Luhman (2019) and the majority classified as T Tauri Stars (TTSs). We studied in the sample the presence of flares and their characteristics, such as duration, peak amplitude, bolometric luminosity and energy released.

Using the TESSExtractor tool (Serna et al., in prep.), we obtained and corrected by systematic effects 643 TESS light curves with a 2 minutes cadence in sectors 43 and 44, alongside the stars' rotation period. We developed a tool called FLAN (FLare ANalizer), which applies a 4th-order Savitzky-Golay filter several times on a light curve to find and de-trend signals not related to the flare. When the light curve is completely normalized, FLAN looks for the presence of flares, detecting at least 1 point $\geq 3\sigma$ over the continuum and two consecutive points $\geq 2.5\sigma$ as the criterion. This allows us to report flares with a minimum duration of 10 minutes.

As a result, we detected 1700 flares. In every positive case, FLAN calculated its duration, amplitude, and area. Stellar parameters such as luminosity and mass, relevant for calculating the flare luminosity, were obtained from the program MassAge (Hernández et al., in prep.). Likewise, the bolometric energy (E_{Bol}) is quantified after integrating the flare luminosity along its duration. Additionally, YSOs tend to have energies between 10^{35-37} erg. When it is compared with M-type stars from Günther et al. (2020) and Solar-type stars from Tu et al. (2021), both classified as main-sequence (MS), we found that YSOs produce systematically more energetic and more frequent flares than MS stars. Therefore, flares become less intense as stars get older (Figure 1).

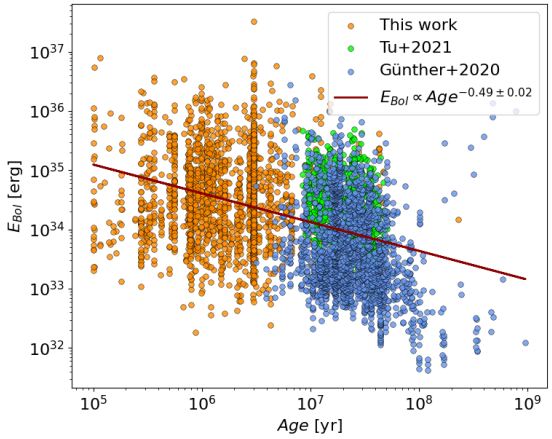

Figure 1. Relation between E_{Bol} and age compared with Günther et al. (2020) and Tu et al. (2021)

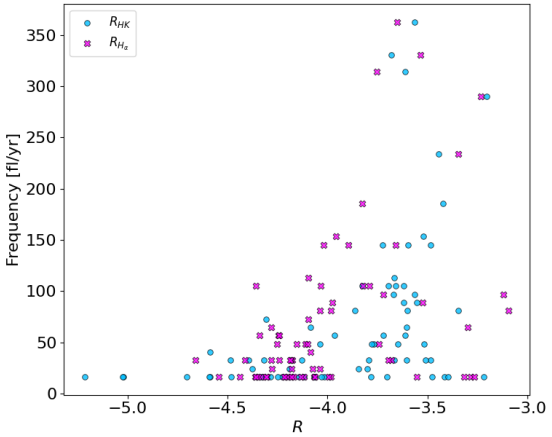

Figure 2. Frequency of flares in 168 stars with LAMOST and FAST spectra in which $R_{H\alpha}$ and R_{HK} is calculated.

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Finally, from LAMOST and FAST spectra of 168 WTTS in our sample, we measured the equivalent widths and the activity index R for H_α and Ca II HK lines. We found that these stars are very active ($R > -5.0$), showing more probability of producing a higher rate of flares (Figure 2). This work was supported by the projects CONACyT No. 86372 and PAPIIT CG-101723.

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Systematic method for identification of L-type variable brown dwarfs

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Keywords: *brown dwarfs, stars: atmospheres, stars: variables: general*

Most brown dwarfs show some level of photometric or spectral variability. However, obtaining light curves for brown dwarfs is a resource-intensive task, since in general at least a few hours of telescope monitoring are required per object to be able to obtain a useful light curve. Thus, selecting the most likely variable brown dwarfs is key to optimally employing resources. A few years ago, the design of spectral indices to find the most probable L and T dwarfs using a single epoch spectrum in the near-infrared presented by Ashraf et al. 2022 and Oliveros-Gomez et al. 2022 gave us an important tool to observe more probable objects to measure their variability.

In this work, we designed and tested near-infrared spectral indices to pre-select the most likely variable L4-L8 dwarfs to broaden the spectral types of brown dwarfs to which this spectral index method can be applied. We used time-resolved near-infrared *Hubble Space Telescope Wide Field Camera 3* spectra of an L6.0 dwarf, LP 261–75b, to design our novel spectral indices (six in total) analyzing in detail the regions in the spectrum and their variation in time. We improve the method, using machine learning to classify the variable and non-variable spectra and obtain an index-index plot more accurately (shown in Figure 1). We did a histogram showing how many variable or non-variable areas typically each of the variable or non-variable are found. Using the histogram, we defined the variability threshold in 9/15 index-index plots. The spectra/objects found in more than 9 out of 15 variable areas are classified as *variable candidates*.

We tested these spectral indices on 75 L4.0-L8.0 near-infrared SpeX/IRTF spectra, providing 27 new variable candidates for brown dwarfs. Using the reports about variability of some objects of our initial sample we obtain a recovery rate of our indices method of ∼92%, and a false negative rate of ∼25%. Also, all the known non-variable brown dwarfs were found to be non-variable by our indices.

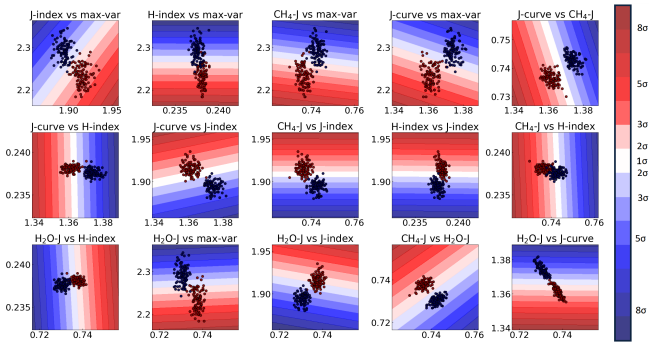

Figure 1. Index-index plot, using the synthetic spectra generated with the Monte Carlo method from the HST/WFC3 spectra of LP 261-75b. The flux maximum spectra are shown as red dots, and the flux minimum spectra are shown as blue dots. We show the areas of variability computed using *machine learning* (`scikit-learn`) with their respective reliability regions.

We estimated the variability fraction of our sample to be 51^{+4}_{-38} %, which agrees with the variability fractions provided by Buenzli et al. 2014, Radigan et al. 2014 and Metchev et al. 2015 for this spectral range of L4–L8 dwarfs. These spectral indices may support in the future the selection of the most likely variable directly-imaged exoplanets for studies with the *James Webb Space Telescope* and as well as the 30-m telescopes.

The Python code to find variable candidates using the spectral indices presented in this work is publically available in Github: https://github.com/ntlucia/BrownDwarf-SpectralIndices.

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A surprising dynamical mass for Oph-S1

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Keywords: *stars: binaries: general, stars: pre-main-sequence*

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Combining 35 Very Long Baseline Array observations of the intermediate-mass young stellar object S1 in the Ophiuchus complex, we determine the dynamic masses of the two members of the system to be 4.11 ± 0.10 $M_\odot$ and 0.831 ± 0.014 $M_\odot$. The mass of the primary is at least 25% higher than expected from stellar evolutionary models.

Very long baseline interferometry (VLBI) provides images with an angular resolution of order one milliarcsecond (mas) and an astrometric accuracy better than 0.1 mas relative to distant quasars. This can enable accurate determinations of *individual* masses in a tight stellar system if multi-epoch observations are combined. In this contribution, we report on such observations of S1, the most luminous and massive stellar member of the Ophiuchus star-forming region. Oph-S1 has long been known to be a binary intermediate-mass young stellar system, and provides a rare opportunity to obtain empirical constraints on theoretical models of stellar evolution for that mass range. The measured positions of the two components of Oph-S1, S1A and S1B, of the system relative to their center of mass are shown in Figure 1, together with the best Keplerian fits. The masses deduced from these fits are 4.11 ± 0.10 $M_\odot$ for S1A and 0.831 ± 0.014 $M_\odot$ for S1B.

Existing optical and infrared photometric observations of S1A can be interpreted as a reddened blackbody, but there is a significant degeneracy between the temperature of the blackbody on the one hand, and the stellar radius and amount of foreground extinction on the other (Ordóñez-Toro et al., 2024). Temperatures between 14,000 K and 17,000 K provide adequate fits, but for different values of the luminosity – between about 700 $L_\odot$ and 2,100 $L_\odot$, respectively. Regardless of the chosen $(T_{\rm eff}, L)$ combination, however, S1A falls above the ZAMS in the HR diagram, suggesting an age of order 0.5 Myr. On the other hand, the theoretical evolutionary track for a 4 $M_\odot$ star (e.g. Tognelli et al. 2011) falls significantly below the locus of S1A in the HR diagram. Conversely, if theoretical models were used to estimate the mass of S1A from its position in the HR diagram, they would suggest a mass of 5 to 6 $M_\odot$, at least 25% higher than measured dynamically. In contrast, the dynamical mass of S1B is reasonably consistent with its de-reddened absolute K magnitude ($M_K \approx 1 \pm 0.5$) deduced from the scant resolved infrared observations of the S1 system.

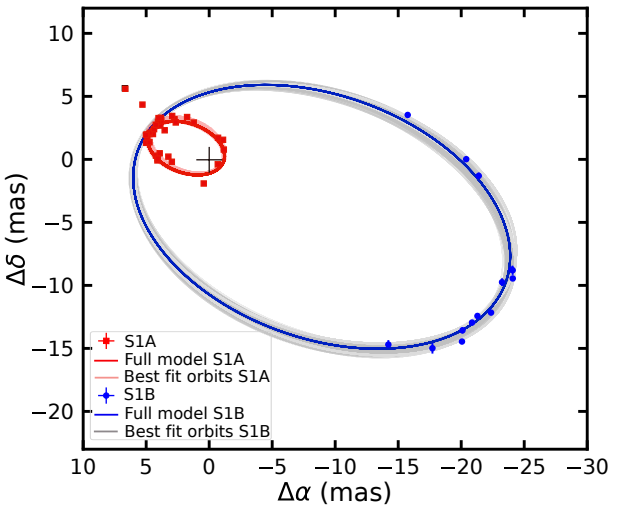

Figure 1. Orbits of S1A (red) and S1B (blue) relative to the center of mass (black cross). To illustrate the range of solutions allowed by the errors in our fit, 100 orbits are shown in light red for S1A and grey for S1B. The measured positions of S1A (red squares) and S1B (blue circles) after correction of parallax and proper motions are also shown. Position errors are on the order of 0.1 mas, barely seen at the scale of the plot. Adapted from Ordóñez-Toro et al. (2024).

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Survival of fossil fields during the pre-main sequence evolution of intermediate-mass stars

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Keywords: *H II regions, ISM: jets and outflows, stars: mass-loss, stars: pre-main-sequence*

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Chemically peculiar Ap/Bp stars host strong magnetic fields in the range of 200 G to 30 kG. Here we discuss their possible origin in terms of fossil fields from the interstellar medium and their survival during protostellar evolution.

The origin of strong magnetic fields in chemically peculiar Ap/Bp-type stars is still controversial. A possibly important origin involves fossil magnetic fields from the interstellar medium, which however need to survive the protostellar evolution of the star (Braithwaite & Spruit, 2017). During the convective phase, this is very difficult, and the magnetic field is likely to be efficiently dissipated, unless the magnetic energy is at least comparable to the convective energy and thus able to efficiently suppress convection (Moss, 2003).

A possible alternative has been sketched by Dudorov & Tutukov (1990). If protostars become radiative during their evolution, then at least the mass accreted during the later phase of the protostellar evolution is likely to remain magnetised, inheriting and maintaining the magnetic field from the interstellar medium. Protostellar evolution models by Palla & Stahler (1991) indeed have shown that protostars exposed to constant accretion rates

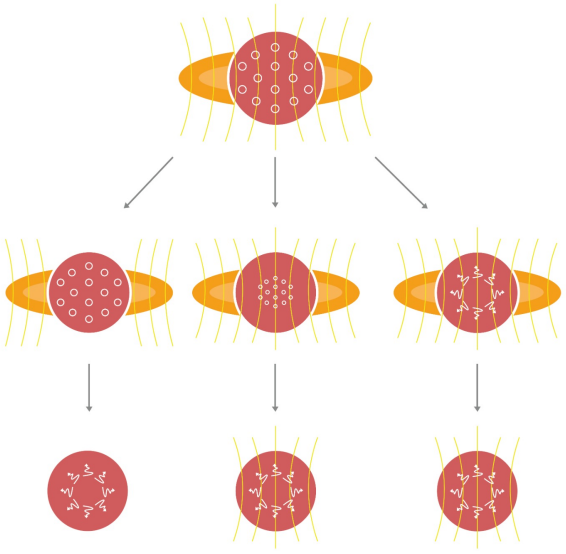

Figure 1. Possible evolutionary pathways of a convective protostar with a magnetic field. Left: Dissipation by convection. Middle: Magnetic field suppresses convection. Right: Protostars becomes radiative and magnetic field survives. Figure from Schleicher et al. (2023).

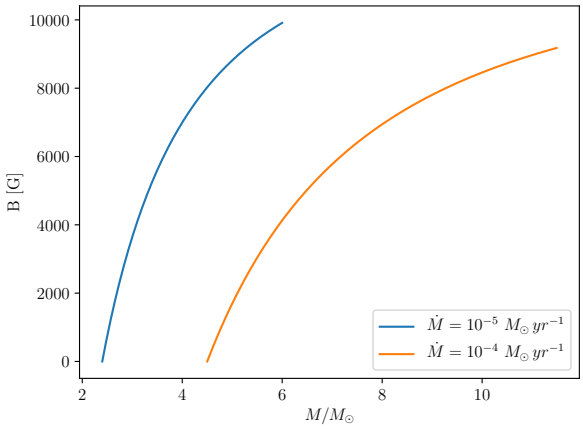

Figure 2. Expected magnetic field strength as a function of stellar mass considering the evolutionary models of Palla & Stahler (1991). Figure from Schleicher et al. (2023).

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of $\sim 10^{-5}$ $M_\odot$ yr^{-1} become radiative after reaching a mass of about 2.4 $M_\odot$. The pathways are summarized in Figure 1, and an estimate of the field strength that could be obtained from the Palla & Stahler (1991) models is given in Figure 2 as a function of stellar mass.

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Analysis of the parameters in the evolution of viscous accretion disks in Be stars for the L spectral band

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Keywords: *H II regions, ISM: jets and outflows, stars: mass-loss, stars: pre-main-sequence*

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In our research, we employ Bayesian inference techniques to determine the parameters of disk models for 24 Be-type stars located in the northern galactic region. We compare these models with the observed fluxes in the L band of the infrared spectrum. Our analysis focuses on distinctive spectral lines, such as Brackett α, Pfund γ, and Humphreys 14. We have discovered a significant correlation between key parameters like surface mass density and the 'n' parameter in a potential equation.

Main sequence Be stars are stars that have shown or currently show emission lines. These stars are surrounded by a circumstellar disk, making them ideal candidates for studying stellar variability, also known as the Be phenomenon (Porter & Rivinius, 2003).

One way to classify the variability of disks is through the Lenorzer diagram, which allows the identification of stars in groups I or II according to the classification proposed by (Mennickent et al., 2009). These groups are distinguished by the ratios between the characteristic lines Brackett α, Pfund γ, and Humphreys 14, belonging to the L-band of the infrared spectrum Figure 1.

One way to compare and gather information about the disks is by using synthetic spectra, which were modeled using the HDUST code (Carciofi & Bjorkman, 2006). This comparison is made using Bayesian models, which allow for the determination of the posterior distribution of the parameters. Specifically, we use a grid of BeAtlas stellar models, defined by the prior expressed in equation (1):

$$\pi(\theta \mid \mathcal{H}) \propto M^{-2.3} f_{\rm Be}(M) \exp\left(-\frac{(W-\langle W\rangle)^2}{2\sigma_W^2}\right) \Theta(\theta \mid \mathcal{H}, \tag{1}$$

where, the factor $M^{-2.3}$ represents the initial mass function (IMF) as defined by Kroupa (2001), and $f_{\rm Be}(M)$ indicates the fraction of Be stars compared to the total number of B and Be stars. Additionally, the Gaussian factor is derived from the distribution of rotational velocities W in the Be star sample, based on (Rivinius et al., 2006). This assumes an average rotational velocity $\langle W\rangle = 0.81$ and a standard deviation $\sigma_W = 0.12$. Lastly, Θ is a parameter vector associated with various factors including the star's mass $M_\odot$, disk surface density Σ_0, disk inclination *cosi*, rotational velocity W, and 'n', representing the power law of the potential.

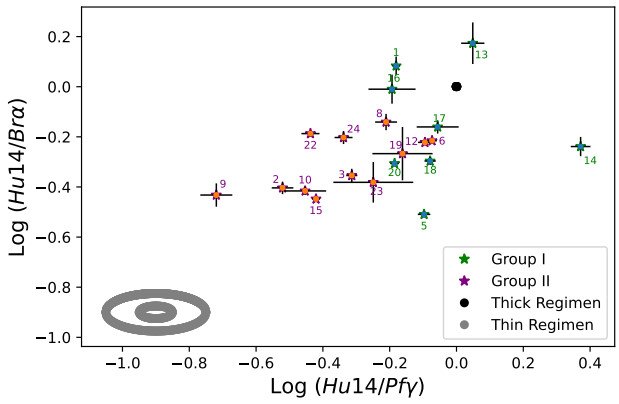

Figure 1. Lenorzer diagram for Group I and II stars, where the grey area represents the optically thick regime.

By using the Emcee code to estimate the disk parameters, we have found that this analysis enables us to effectively crossmatch theoretical and observational data. This is crucial for validating the accuracy and relevance of our models in the astrophysical study of Be star disks, in the infrared region for the L-band.

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Identifying T Tauri stars in the Milky Way using machine learning and LAMOST spectra

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Keywords: *stars: pre-main-sequence, stars: variable: T Tauri, Herbig Ae/Be*

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OB associations are low-density groups of young stars. Because their OBA-type members are more massive and therefore brighter, the OB associations are primarily characterized by these stars (Wright, 2020). In contrast, their low-mass members are less identified, despite being more numerous. Improving our understanding about stellar formation requires the identification of low-mass members, such as T Tauri stars (TTS).

TTS are low-mass stars, $< 2M_{\odot}$, in the pre-main sequence. They are considered precursors of planetary systems (Briceño et al., 2019). Their optical spectra show an absorption line of LiI, which is an indicator of youth. TTS are classified into two categories: classical TTS (CTTS) and weak-line TTS (WTTS). The CTTS exhibit H_{α} line emission caused by a circumstellar disk, while in WTTS, the H_{α} line is relatively weak and is attributed to chromospheric activity. In general, this emission depends on their evolutionary state. Other significant optical spectral features of TTS include TiO and VO bands, which give an account of the stellar effective temperature.

The Chinese Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)[1], generates 4000 spectra in a single exposure providing a large amount of spectra in the wavelength range of 3700 to 9000 Å. In the public data release DR8, there are approximately 10 million low-resolution spectra (R≈1800).

The large amount of data generated in modern telescopes, like LAMOST, demands modern approaches to data treatment. Machine learning (ML) is an essential tool that offers several solutions to this problem (Zhang & Zhao, 2015).

We present results on the detection and spectral classification of TTS in the Orion Star Forming Complex (OSFC) using ML techniques and LAMOST spectra.

To detect TTS, we conducted automated equivalent width (EW) measurements on H_{α} and LiI lines, as well as TiO and VO bands for 342 TTS from the Ori OB1a substellar association, as reported by Hernández et al. (2023). We incorporated a set of non-TTS (field stars) in the training sample. Subsequently, we implemented a Logistic Regression model (LR) for binary classification. This supervised ML algorithm assigns a value probability of being TTS or not through a sigmoid function:

$$p(m_i, \theta_i) = \frac{1}{1 + e^{-m_i \theta_i}}. \quad (1)$$

Where m_i represents the EW measures of low-correlated variables, such as LiI, H_{α}, TiO5, TiO6, and VO1; and θ_i denotes a set of parameters to be determined. The model assessment was conducted using the F1 score, resulting in a value of 0.92 and an accuracy of 0.94 for the positive class, indicating good performance.

In the cross-match between Gaia DR3 and LAMOST DR8, 5800 spectra were obtained from the OSFC, and measurements were successfully obtained for 5046 of them. By considering measurement errors, a probability greater than 0.90 was determined for 1331 spectra, indicating their likelihood of being T Tauri stars (TTS).

Finally, for the spectral classification of TTS, we employed EW measures on synthetic spectra ranging from spectral type K0 to K7 and M0 to M9, obtained from the stellar atmosphere code PHOENIX. Subsequently, by applying a Principal Components Analysis transformation to the measures, we implemented various multi-class models, among which a Gradient Boosting Machine model exhibited superior performance metrics in preliminary assessments. The aforementioned work is still in the development stage.

[1] http://www.lamost.org

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ALMA imaging of the complex, dynamical atmosphere of the AGB star W Hya at 20-milliarcsecond resolution

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Keywords: *stars: AGB and post-AGB, stars: mass-loss*

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We present 20-milliarcsecond resolution ALMA imaging of the well-studied AGB star W Hya at 250–269 GHz. The high resolution of our ALMA observations allowed us to spatially resolve the detailed structures of the mass loss within ∼100 mas (5 stellar radii).

The mass-loss mechanism in asymptotic giant branch (AGB) stars is not yet fully understood. It is often argued that the combination of the levitation of the atmosphere by stellar pulsation, dust formation, and radiation pressure on dust grains can drive the mass loss (Höfner & Olofsson, 2018 and references therein). The recent high spatial resolution imaging reveals inhomogeneous structures over the surface and atmosphere of AGB stars seen in infrared molecular lines (Ohnaka et al., 2019) as well as clumpy dust formation within ∼2 stellar radii (Khouri et al., 2016; Ohnaka et al., 2016, 2017; Adam & Ohnaka, 2019), as predicted by the 3D dynamical models (Höfner & Freytag, 2019; Freytag & Höfner, 2023). Also, the shocked atmosphere leads to non-equilibrium chemistry, which is important for dust formation (e.g., Gobrecht et al. 2016). Therefore, it is crucial to spatially resolve the region within several stellar radii, where the stellar wind accelerates, in order to better understand the mass-loss mechanism.

W Hya is one of the best-studied, nearby AGB stars. Thanks to its high brightness and proximity (98 pc, Vlemmings et al. 2003), it has been observed with different techniques from the ultraviolet to the radio. We observed W Hya with ALMA in Band 6 at 250–269 GHz, using a maximum baseline of 16 km, which resulted in a beam size of ∼16×20 mas (Ohnaka et al., in prep). The millimeter continuum emission has an angular diameter of ∼60 mas, which is ∼1.5 times larger than the stellar angular diameter measured in the near-infrared (Woodruff et al., 2009). We identified nearly 60 molecular lines, which include ^{29}SiO, ^{30}SiO, Si^{17}O, H_2O, SO_2, SO, HCN, AlO, AlOH, TiO, and OH. The asymmetric molecular emission extends to ∼100 mas (∼5 stellar radii) with a plume extending in the NNW, a tail extending in the SSE, an extended atmosphere elongated in the ENE-WSW direction, and many clumpy structures.

The beam size of ∼16×20 mas allowed us to see the spectral lines in absorption over the stellar disk as we expect. The absorption is not uniform over the stellar disk, indicating inhomogeneities in the density and/or temperature. However, surprisingly, approximately a third of the identified lines show emission over the stellar disk. The lines of ^{29}SiO $v = 2$ $J = 6 - 5$ at 253.703 GHz and the vibrationally excited H_2O $v_2 = 2$, $6_{5,2} - 7_{4,3}$ at 268.149 GHz show particularly strong emission over the stellar disk, which we interpret as maser actions. The emission from certain lines of ^{30}SiO, Si^{17}O, SO_2, and AlO is less prominent, which can be interpreted as weak maser actions and/or masers attenuated by absorption due to overlying layers.

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Damping of surface Alfvén waves in accretion disks

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Keywords: *accretion, accretion discs, magnetohydrodynamics MHD*

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The transport of angular momentum and matter is essential for the evolution of astrophysical disks, particularly protostellar disks. Recently, several works investigated the role of non-ideal MHD effects in those objects and their impact on angular momentum transport. On the other hand, the damping of Alfvén waves was already proposed as a viable mechanism for disk heating, increasing its ionization fraction and, consequently, the region of the disk subject to Magneto-Rotational Instability. In this work, we analyze the effects of the resonance of surface Alfvén waves in protostellar disks with a local approximation, in the presence of both resistivity and viscosity. In general, we find that depending on the propagation properties, the waves may be damped or amplified, and these processes are independent of the dissipation coefficients, at least for the hypotheses adopted.

The angular momentum (AM) transport is a key process to describe various astrophysical systems, including accretion disks found around young stars. The transfer of AM is necessary to promote the evolution of these protostellar disks, however, is still a matter of debate, with several mechanisms proposed to explain this transportation, including the Magneto-Rotational Instability (MRI, Balbus & Hawley 1991). In the last years, though, it was found that in the partially ionized disk, the presence of nonideal MHD effects may diminish the effectiveness of this instability, or even suppress it entirely, in the sense that extra mechanisms may be taken into account (e.g. Bai 2011).

Vasconcelos et al. (2000) proposed the damping of Alfvén waves as a source of non-thermal disk heating, which could provide the additional ionization process necessary to guarantee the AM transport. Jatenco-Pereira (2013) also considered the damping of those waves for dusty disks. In the present work, we explore this hypothesis further, by considering the resonance of surface Alfvén waves. To provide an analytical approach to our problem, we use the fact that surface waves propagate at the interface between two media and apply a local approximation. In this approximation, we may define a new cartesian system of coordinates, centered at a reference point, r_0, which allows us to write the radial shear associated with the disk differential rotation as $\mathbf{v_0} = -q\Omega_0 x\hat{\mathbf{y}}$, where q corresponds to the power-law index of the angular frequency, $\Omega \propto r^{-q}$, Ω_0 is the angular frequency at our reference point, r_0, and x corresponds to our local radial coordinate. With this simplified model, if we apply incompressible perturbations of the form $g(x,y,z,t) = g(x)\exp\left[i(-\omega t + k_y y + k_z z)\right]$, and assume that $k_y a, k_z a \ll 1$, where $2a$ is the width of the region where the local approximation is valid, with $k_y > k_z$, we find, through the perturbation method that, depending on the propagation properties, an instability may be triggered in the system or a damping regime is achieved. Indeed, for what we call the *forward* case, where $\mathrm{sign}(\omega_0/\omega_A) > 0$, where ω_0 is the real principal part of the perturbation frequency, and ω_A is the Alfvenic frequency, a shift in the regime occurs: initially, the wave is amplified, due to the development of instability and as we increase the velocity shear, a damped regime is achieved. For the backward case, on the other hand, the wave is always damped. We also quickly compared the damping rate obtained with our mechanism and the turbulent damping, already studied in the literature as a source for non-thermal disk heating (see Vasconcelos et al. 2000). We found that, under reasonable conditions, resonant damping is more effective than turbulent damping in heating the disk, indicating that the proposed mechanism can decrease the dead zone extent. We are now performing a more robust numerical analysis to fully describe the effect of the resonant damping of surface Alfvén waves over the ionization fraction and transport of angular momentum in those disks.

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Chemical complexity in simulations of circumstellar discs formation

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Keywords: *ISM: abundances, ISM: clouds, protoplanetary discs, stars: circumstellar matter*

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Accurately modelling complex chemistry in numerical simulation is challenging, and is often avoided by relying instead on post-processing techniques. This implies computing the evolution of chemistry over the dynamic history of particles within the raw data. Our aim is to study complex chemistry over existing smoothed particle hydrodynamics (SPH) simulations of star cluster formation by employing this technique over the simulation data.

The base simulation employed in this study is the solar metallicity case of the four radiation hydrodynamical simulations presented in Bate (2019), which evolves a low mass clump of 500 $M_{\odot}$, performed using the smoothed particle hydrodynamics code SPHNG. Each calculation uses about 3.5×10^7 SPH particles to model the cloud.

To perform this study we apply a slightly modified version of the post-processing routines presented in Ferrada-Chamorro et al. (2021) to a small fraction of the entire particle set, by employing the chemistry package KROME (Grassi et al., 2014) to analyze and recover the abundances of different chemical species over the simulation data.

We first extract a small subset at the end of the simulation enclosing a small rectangular region with side $\sim$ 0.01 pc nearly at the center of the cloud resulting in a $\sim$ 330000 SPH particle subset. This data is extracted in GIZMO compatible files in order to correctly apply the post-processing routines presented above. To correctly model chemistry over the data we need to extract some important local properties on which chemical reactions depend (i.e., temperature, density, visual extinction A_v). We also need to specify a chemical network, which includes the tracers we want to study under the given conditions. In our case we employ a basic H-C-O network including molecules like CO and H2O.

The output of the post-processing are new snapshots including information for the chemical species indicated in the chemical network, allowing us to study them over the data without the need to recreate the simulations with on-the-fly (OTF) chemistry.

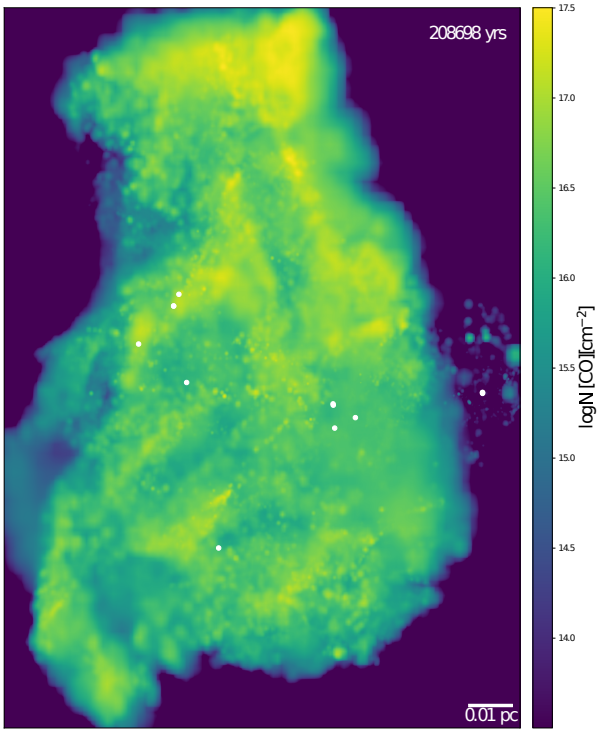

Figure 1. CO column density map for the sub-region at time $t \approx 1.1\ t_{\rm ff}$. Stars are plotted using white dots.

The purpose of using this method instead of just OTF chemistry is the large reduction of computational cost and the accuracy achieved when performing these post-processing routines, as already pointed out in Ferrada-Chamorro et al. (2021).

In Fig. 1 we report a CO column density map for the sub-region at an advanced stage by performing the post-processing routines over the data.

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A systematic method to identify runaways from star clusters produced from single-binary interactions: A case study of M67

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Keywords: *galaxies: star clusters: general, radiation: dynamics*

We create a methodology to look for runaway pairs produced from triple disintegrations from single-binary interactions. We search for these pairs in the cluster M67, from which the binary and single produced from the interaction should have been ejected. One pair passes all of our selection criteria.

Stars ejected from a star cluster with unusual kinematics are known as runaway stars. They can be ejected either by supernova explosions in binaries or the disintegration of triple systems (e.g. Renzo et al. 2019; Leigh et al. 2020; Toonen et al. 2022). Our aim is to find observationally the products of triple disintegrations interactions, that produce a runaway star (RS) and a runaway binary (RB). Their relative velocity vectors are determined by linear momentum conservation. We use Gaia DR3 data to search for these interactions. We define our selection criteria as follows: Velocity vectors of the objects should have a 180° angle between them. The mass and luminosity of the RB should at least double the mass of the RS. RS should have a velocity $>$ 2 that of the RB. Both traceback times from the currently observed positions to the hypothetical origin should be equal. Position in the CMD compared with known M67 stars. From GAIA DR3, we searched a circular area with a radius of 150 pc centered on M67's CoM. We apply a cylindrical cut using the parallaxes, with a length of 300 pc. We keep sources with velocities greater than the cluster escape velocity $v_{esc} > 2.6$ km s^{-1}, relative to the CoM motion of M67. We combine each remaining source, producing nearly 120 million pairs. Each of our criteria reduces the total number of pairs as follows: **(1)** For the velocity ratio criterion, the sample is reduced by a factor of about 2. **(2)** Requiring that the dimmer object be faster reduces our total sample size by one order of magnitude. **(3)** The traceback time criterion reduces the total sample by one order of magnitude. **(4)** Requiring that the angle between the velocity vectors be consistent with 180 degrees decreases our sample size by two orders of magnitude. **(5)** Requiring that the fastest and dimmer star lies in the CMD in a location consistent with an isochrone and that the binary lies slightly above the isochrone, reduces our sample size by two orders of magnitude. After applying all of our

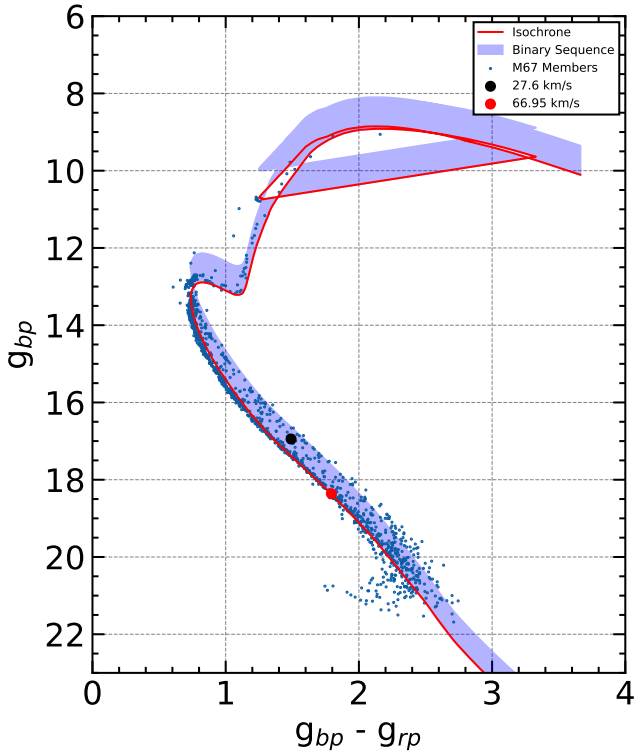

Figure 1. CMD of M67, with high-probability members in Childs et al. (2024) as the small dots. Red lines show the best-fitting isochrone as well as the equal-mass binary sequence shifted 0.75 mag above it. Resulting pair, red and black dots, are the faster and slower-moving objects.

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criteria, we are left with only one pair that satisfies them all simultaneously. Our sample size is reduced by eight orders of magnitude, from $\sim 10^8$ to 1. It is important to validate our method by applying it to other star clusters. Our candidate pair that we identify is still highly preliminary, and subsequent observations should be performed.

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The metallicity gradient of sagittarius dwarf spheroidal galaxy prior to infall constrained by S-PLUS observations of its tidal stream

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Keywords: *stars: abundances, galaxies: kinematics and dynamics, galaxies: structure*

Several major substructures, like the Sagittarius stream, have been observed in the Milky Way halo over the past few years. These substructures are likely remnants of past accretion events, therefore, investigating their origin and nature is crucial to understanding the formation and evolution of our Galaxy in the context of hierarchical galactic formation. In this study, we used photometric metallicities to study the current metallicity gradient in the arms of the Sagittarius stream, and compared these results to predictions of N-body simulations to reconstruct the original metallicity gradient in the Sagittarius dwarf galaxy prior to its accretion by the Milky Way. To build our sample, we did a cross-match between S-PLUS (Mendes de Oliveira et al., 2019) DR4 photometry and a list of Sagittarius stream members from Ramos et al. (2022), which were selected using astrometric data from Gaia DR3. We applied two different techniques to estimate photometric metallicities: an artificial neural network and a random-forest algorithm, resulting in two samples of, respectively, 7398 and 4683 stars with reliable metallicity measurements. We measured a gradient of ≈ -0.0030 dex/degree for the leading arm of the stream. For the trailing arm, we found no significant gradient when considering the whole area covered by S-PLUS ($20 \leq \Lambda \leq 130$ degrees). However, the region near the core ($20 \leq \Lambda \leq 70$ degrees) also presents a

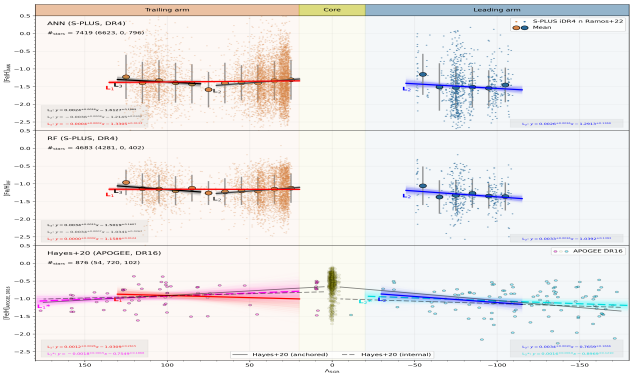

Figure 1. Metallicity of stars members of the Sagittarius stream as a function of their longitudinal position across the stream. The top and middle panels correspond to the photometric metallicity derived from S-PLUS DR4 using artificial neural networks (top) and random forest (middle). The trailing arm is represented in red, while the leading arm is represented in blue. The gradients were measured using least squares linear regression and uncertainties were obtained by using a bootstrap technique. For comparison, the bottom panel shows the spectroscopic metallicities of APOGEE DR16 and gradients measured by Hayes et al. (2020).

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gradient of ≈ -0.0035 dex/degree. We show that our photometric metallicities reproduce the result of , when the same longitudinal intervals are considered. We imprinted artificial metallicities to particles in a N-body simulation (Vasiliev et al., 2021) considering different scenarios of original metallicity gradients. Comparing simulated and observed results, we were able to show that the current metallicity gradient in the stream is consistent with an original metallicity gradient between -0.22 and -0.37 dex/kpc in the Sagittarius progenitor galaxy.

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Understanding the impact of binary mass transfer in the accretor's measurable parameters

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Keywords: *accretion, accretion discs, blue stragglers, stars: evolution, stars: mass-loss*

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In the context of binary evolution, details of the effects of direct mass accretion on a star's observable properties remain largely uncertain. In this work, we aim to further our understanding on the underlying physics using a novel analytic model for binary mass transfer. We find that a star's spin-up is most effective when the binary is close to tidal locking.

With a simplified model, Packet (1981) was among the first to note that accreting just 10% of a star's initial mass should spin it up to its critical rotation rate. This would make most mass accretion products rapid rotators. These, however, have been observed to prefer low-density environments (Ferraro et al., 2023) where wider systems have a higher survival rate due to the lower frequency of strong dissociative dynamical interactions. We aim to address these results using a more complex model than is often assumed for accretion, so as to characterize the changes in the observational properties of an accreting star due to mass transfer in a binary system, as a function of the system's initial conditions.

Fixing the accretor at the origin, $L1$ traces an ellipse around it. In order to measure the effects of direct accretion through a stream, we make the following assumptions: (i) the effect of the donor's potential on an infalling parcel of mass is negligible beyond $L1$, (ii) a stream can be built by superposition of parcels, (iii) the radial component of the velocity at impact onto the accretor contributes to its thermal energy and (iv) its tangential component contributes to its rotational energy.

At $L1$, a parcel's velocity must be lower than the orbital motion in order to move in a tighter orbit and approach the accretor star. In order to guarantee a direct impact, eq. 1 must be satisfied.

$$|v_i| \leq \sqrt{\frac{2Gm_{acc}}{d_{L1} + d_{L1}^2/r_{acc}}} \qquad (1)$$

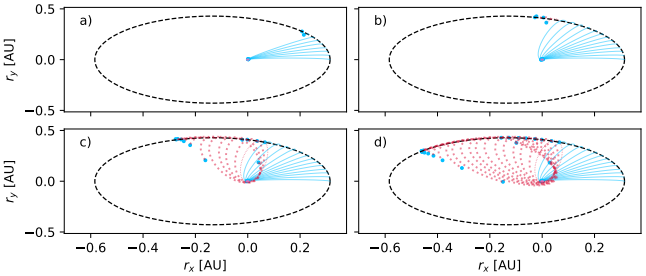

Figure 1. From a) to d), the system at times 20, 40, 60 & 80 days. In blue, the trajectory of a parcel that starts at $L1$ (dashed black line) and directly impacts the accretor (pink dot). In red, trajectories that fail to hit the star.

Here, m_{acc} and r_{acc} are the accretor's mass and radius and d_{L1} is the distance to $L1$. Knowing the donor's orbital velocity $v_{don,o}$, the opposing velocity is constrained by $v_i - v_{don,o} \leq |v_{ex}| \leq v_i + v_{don,o}$. This is measured at periapsis where the greater $v_{don,o}$ provides a wider range for v_{ex}. The maximum orbital separation is set so the donor's radius exceeds its Roche radius (Eggleton, 1983) at apoapsis.

A parcel is let go at each point of the $L1$ orbit and, from its initial velocity and velocity angle with respect to the radial direction, a new trajectory is defined (see fig. 1). This is repeated for different values of the extra velocity component v_{ex}, the semi-major axis a, and the eccentricity e while keeping the other two parameters and the mass ratio fixed. By analyzing the contribution from the tangential and radial components we find: (i) In all cases, the tangential component dominates through the whole range of values (i.e. spin up is favored), (ii) the contribution to spin peaks at $|v_{ex}| \sim |v_{don,o}|$ which suggests systems that are close to being tidally locked, and therefore have a higher v_{ex} than expected for a giant's rotation, are more effective at spinning up a star and, (iii) for the a and e samples, the total tangential component stays mostly constant, however, if we were to restrict v_{ex} to lower values (e.g. $\leq$ 10 km/s),

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systems with larger a where the $v_{don,o}$ is lower would be the most effective at spinning up stars.

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Constraining the physics of rotation in stellar interiors

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Keywords: *asteroseismology, stars: evolution, stars: interiors, stars: rotation*

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In this contribution I review the current theoretical description of angular momentum transport in stellar interiors, constrained by results obtained with asteroseismic techniques.

Space-borne missions such as Kepler or Tess provided light curves of unique quality for stars in different evolutionary phases, which enabled their asteroseismic characterization by exploiting the properties of their pulsation modes. Initial studies based on those data revealed that the internal rotation rates of red giants are two to three orders of magnitude lower than what stellar models with pure hydrodynamical processes predicted. Moreover, the problem of inefficient angular momentum transport in stellar models is present in several evolutionary phases and for different types of stars. Nowadays, measurements on the inner rotation rates of stars are available for hundreds of stars in different evolutionary phases, and different masses (Aerts, 2021).

Currently, the presence of magnetic fields in stellar interiors provides the best agreement with observations. This is achieved through a dynamo process based on the combined action of differential rotation and the Tayler instability which acts on the azimuthal component of magnetic fields; this process is known as the Tayler-Spruit dynamo (Spruit, 2002). Based on this theory, a better agreement with observations was obtained, although a revision of the theory, as proposed by Fuller et al. (2019) improved the theory drastically for post-main sequence stars. This led to major achievements such as the successful reproduction of core rotation rates of red giants and white dwarfs (Fuller et al. 2019), the rotation profile of the Sun and its surface lithium and helium abundances (Eggenberger et al., 2022), and the near-core rotation rates and surface rotational velocities of low-mass main sequence stars (Moyano et al., 2023).

An illustration of the evolution of the core-rotation rate is shown in Figure 1, where we show the results obtained in stellar evolution computations assuming either models with and without internal magnetic fields, from the ZAMS until the end of the core-helium burning phase.

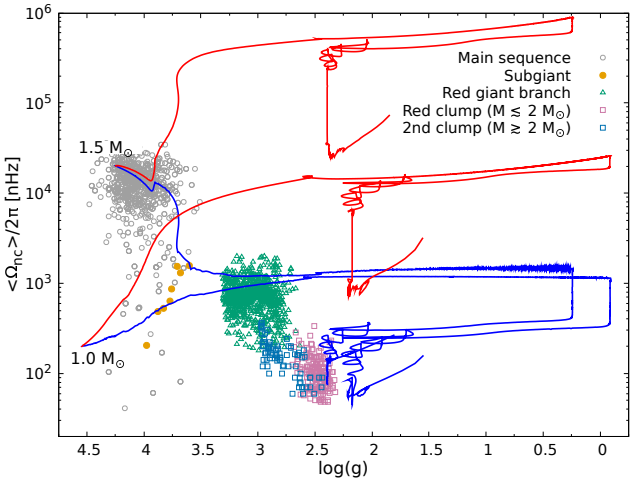

Figure 1. Near-core rotation rate as a function of the surface gravity. The data points correspond to stars in different evolutionary phases as explained in the legend, while the lines correspond to four different stellar evolution models computed from the ZAMS with (blue) and without internal magnetic fields (red) at two different initial rotation rates. The initial masses of the models are indicated in the plot.

However, despite the advances brought by this theory, various problems remain open, like the rotation rates of subgiants (Eggenberger et al., 2019), the unexplored rotation rates of hot subdwarfs (Charpinet et al., 2018), and the presence of large-scale internal magnetic fields in the cores of red giants (Li et al., 2022).

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Unpuzzling the star formation scenario of the Canis Major stellar nursery

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Keywords: *stars: pre-main-sequence*

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We present preliminary results of ongoing work that aims to investigate the Canis Major star-forming region. Based on optical spectra, we found 27 stars with Li I λ 6708 Å absorption line, which are probably T Tauri stars. We additionally identified a few stars with indications of Hα excess, probably due to accretion, by analyzing photometric data.

The Canis Major Association OB1/R1 (CMa) is a peculiar star-forming region with several proposals attempting to explain its formation history (e.g. Herbst & Assousa, 1977; Reynolds & Ogden, 1978). Recent studies suggest that three runaway stars were probably expelled by successive events of supernovae (SN) that occurred ∼6, ∼2, and ∼1 Myr ago (Fernandes et al., 2019). These events affected the environment and evolution processes of the association's young stellar objects.

Our team acquired optical spectra of more than one hundred stars in the region associated with FZ CMa using the Gemini Multi-Object Spectrograph (GMOS). About 20% of the stars are counterparts of X-ray sources. This population is probably mixed in terms of age, lying between a younger group associated with the star Z CMa (< 5 Myr) and an older one associated with GU CMa (> 10 Myr). Our goal is an attempt to improve the *census* of the young low-mass population, which is essential to investigate the interplay between SN and the CMa star-forming region.

The GMOS data are currently under analysis after a careful data reduction process. We are looking for typical spectral indicators of this evolutionary stage, including the Li I absorption line (λ 6708 Å), which indicates their youth (e.g. Fernandes et al., 2015), and the Hα emission line, used to distinguish disk-bearing stars from stars without active accretion disk.

The preliminary results show the presence of 27 stars with the lithium line, these being the T Tauri stars candidates (Fig. 1). In addition, we found 5 stars without the Li I line but showing the Hα emission line. These stars could also be young, and further investigation is needed to understand their characteristics.

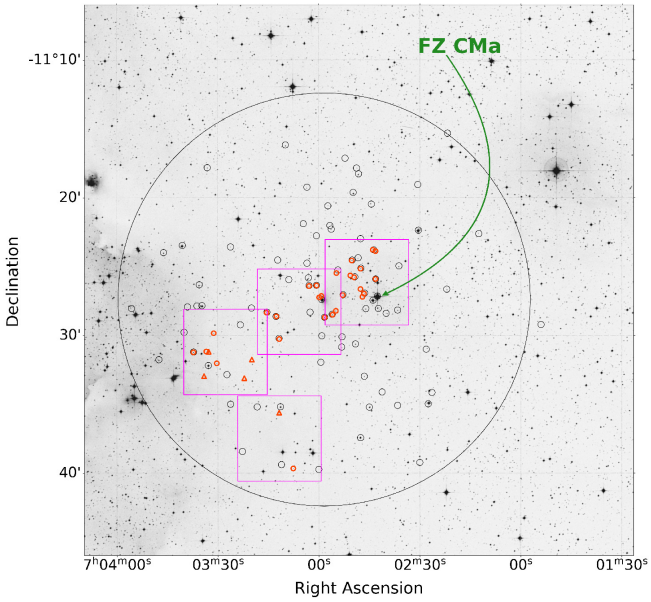

Figure 1. DSS image (R band) from the region associated with the star FZ CMa. Magenta squares: GMOS fields. Black small circles: X-ray sources found by Santos-Silva et al. (2018). Red circles: stars showing the Li I absorption line. Red triangles: stars showing Hα emission, without Li I line.

In parallel, we are exploring multiband photometric data from the 12-filter Southern Photometric Local Universe Survey (S-PLUS) DR4 available for the stars in the region. The results so far indicate the same trends reported by Gregorio-Hetem et al. (2021), however with less scattering. We also found a few stars with indications of Hα excess, likely caused by accretion.

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On the binary origin of short-period Blue straggler stars in Collinder 261

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Keywords: *binaries: general, blue stragglers, galaxies: star clusters: general*

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We study whether binary stellar evolution is a viable formation channel for the short-period blue straggler stars (BSS) in the Collinder 261 open cluster. We find that models with non-conservative mass transfer are plausible progenitors for the fainter observed BSS.

BSS exhibit characteristics of youth, higher temperature, and greater mass than expected according to the standard stellar evolution. They occupy a position above and to the left of the main sequence turn-off point in the optical color-magnitude diagrams (CMDs). The prevailing consensus is that BSS were originally main-sequence stars that acquired additional mass via mass transfer from an evolving primary star through Roche lobe overflow (RLOF), and/or via collisions involving single, binary, or triple stars.

Based on Gaia DR2 data Gaia Collaboration et al. (2018), we focus on the short-period BSS found in Collinder 261. Our investigation delves into the potential of mass transfer in binary systems in accounting for the presence and properties of these stars. We use an adaptation of the binary evolution code presented in Benvenuto & De Vito (2003), which allows us to perform comprehensive calculations on the structure of both stars within the binary system, as well as the orbital evolution and mass transfer rate simultaneously. The aim is to identify potential progenitor candidates matching observations at the same age as that determined for Collinder 261 (namely, $T_c = 7.94$ Gyrs).

Figure 1 shows the observed BSS in the CMD together with simulations of binary systems composed initially by stars of $1.15M_\odot$ and $0.75M_\odot$. We simulate systems under conservative ($\beta = 1$) and non-conservative ($\beta < 1$) mass transfer. In what follows, we detail the initial orbital period (P_i) and mass transfer efficiency (β) of the eight simulated systems: 1) $P_i = 0.80$ d, $\beta = 0.40$; 2) $P_i = 0.80$ d, $\beta = 0.75$; 3) $P_i = 0.80$ d, $\beta = 0.80$; 4) $P_i = 0.85$ d, $\beta = 0.50$; 5) $P_i = 0.87$ d, $\beta = 0.35$; 6) $P_i = 0.87$ d, $\beta = 0.50$; 7) $P_i = 0.90$ d, $\beta = 0.50$; 8)$P_i = 0.92$ d, $\beta = 0.50$.

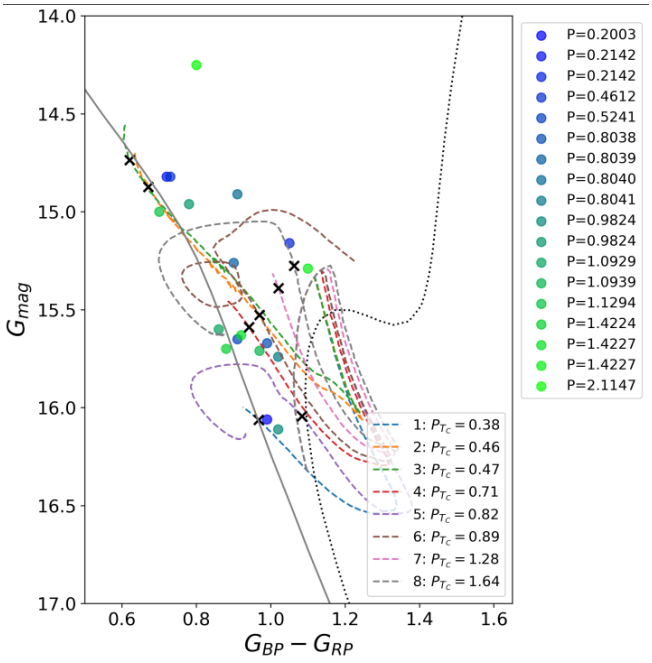

Figure 1. Observed BSS (dots from blue to green) and simulations (dashed lines) in the CMD. Black crosses indicate the moment at which the models reach the age T_c. P indicates the orbital period of the observed BSS in days, and P_{T_c} the orbital period of the simulations at the age T_c in days. The dotted line represents the binary isochrone at T_c and the solid line is the ZAMS.

We find that binary evolution serves as a viable mechanism for producing these BSS and that the efficiency of mass transfer plays a key role in accurately matching the

fainter objects. The orbital period of the simulated binaries at the age of Collinder 261 is in the same range as the one measured in the observed BSS.

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Star formation history of Canis Major OB1 III: stellar group contents revealed by Gaia

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Keywords: *galaxies: star formation, stars: pre-main-sequence*

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In this work, we found 15 physical stellar groups, 4 of which, the youngest, have similar characteristics and must be part of the CMa OB1 stellar association. The discovery of these groups endorses the hypothesis of multiple episodes of star formation and agrees with a monolithic scenario of star formation, with a common formation mechanism.

Our previous works, based on X-ray and infrared data (Gregorio-Hetem et al., 2009; Santos-Silva et al., 2021) we found that Canis Major OB1 (CMa OB1) is a Galactic stellar association having a very intriguing star-formation scenario, which probably had at least three star formation episodes (Fernandes et al., 2019).

To better understand the association stellar population and its star formation history, I recently conducted a study using HDBScan clustering code employing five-dimensional data (RA, DEC, pmRA, pmDEC and parallax) from the *Gaia*-DR2 catalogue to identify physical groups in the vicinity of CMa OB1 and to obtain their astrometric parameters. Additionally, we estimated the age of these groups using two different isochrone-fitting methods (Bonatto, 2019; Monteiro et al., 2020). With this, we confirm the existence of 15 star groups with distances between 570 and 1650 pc, of which 10 are previously known clusters and 5 are new open cluster candidates.

We identified that four younger groups (< 20 Myr), CMa05, CMa06, CMa07 and CMa08, are CMa OB1 contents (see Fig. 1). While CMa06 coincides with the star formation region very well studied by our group, CMa R1, CMa08, one of the new candidate clusters, may be the progenitor cluster of runaway stars that indicate the existence of different star formation episodes in the association. Since the youngest group, CMa06, is still immersed in the remaining material of the molecular cloud associated with the Sh 2-262 nebula, it continues to form stars, the other groups, CMa05, CMa07, and CMa08, seem to be in more evolved stages of evolution, with no recent star-forming activity.

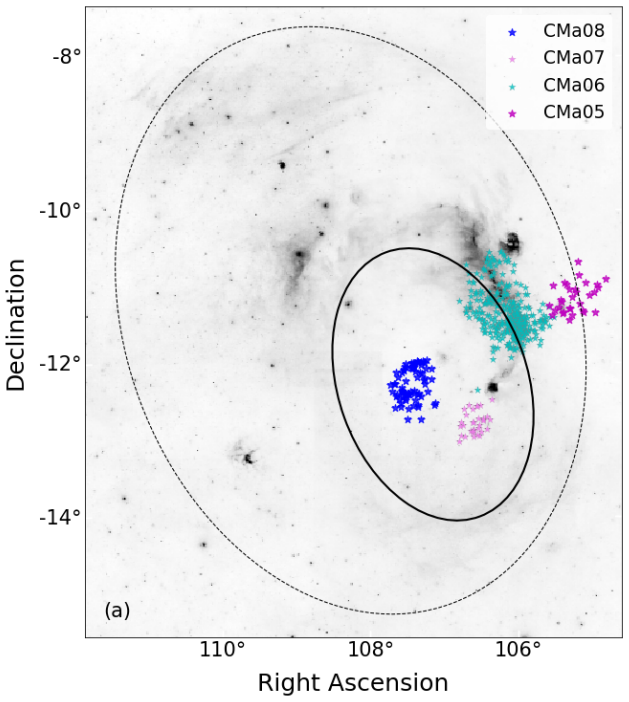

Figure 1. Fig.9 (a) from Santos-Silva et al. (2021). (a) Spatial distribution on Digital Sky Survey image (640 nm) with CMa OB1 groups: CMa05 (magenta), CMa06 (cyan), CMa07 (light pink), and CMa08 (blue).

The results of this work fit well in a monolithic scenario of star formation, with a common formation mechanism, and having suffered multiple episodes of star formation. This suggests that the hierarchical model alone, which

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explains the populations of other parts of the same association, is not sufficient to explain its whole formation history.

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New insights on weak winds in massive stars from hydrodynamical simulations

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Keywords: *outflows, stars: early-type, stars: fundamental parameters, stars: mass-loss, stars: massive, stars: winds*

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We show an overview of the results from de Almeida et al. (2019) about the weak wind phenomenon in massive stars (O-type stars). We present our ongoing study on weak winds based on hydrodynamical simulations and our perspectives to draw a multi-wavelength picture about this phenomenon.

One of the main open questions in the literature about massive stars is the so-called weak wind phenomenon. Weak winds were originally found in late O dwarfs (O8-9V stars), which have luminosity values lower than $\log(L_\star/L_\odot) = 5.2$ (e.g., Marcolino et al. 2009). Quantitative modeling (using radiative transfer models) of the ultraviolet (UV) spectra of these stars indicate $\dot{M}$ of up to 2 orders of magnitude lower than theoretical predictions from Vink et al. (2000).

We present here an overview of the results from de Almeida et al. (2019). This study derived the fundamental stellar and wind parameters of nine late O giants (O8-9III) from modeling their UV and visible spectra using the non-LTE radiative transfer code CMFGEN (Hillier & Miller, 1998). de Almeida et al. (2019) showed for the first time that more evolved massive stars, late O giants, present the weak wind phenomenon, where the derived $\dot{M}$ are much lower (by up to 10^2) than the values predicted using the Vink mass-loss recipe (Vink et al., 2000). This work shows that the luminosity value of $\log(L_\star/L_\odot) = 5.2$ is indeed critical for the onset of weak winds in O-type stars.

We also present our ongoing study of weak winds from coupling radiative transfer models with hydrodynamical simulations using the code HYDWIND (Curé & Rial, 2007). Fig. 1 shows our very preliminary results based on Hα spectroscopy for the weak wind O9V star HD 46202, with synthetic profiles calculated using CMFGEN and FASTWIND (Puls et al., 2005). The Hα line is well reproduced using both codes with the solved hydrodynamics by HYDWIND. For this star, we derived $\dot{M} = 1.3 \times 10^{-9}\ M_\odot\ \mathrm{yr}^{-1}$, that is, in the weak wind regime ($\dot{M} < 10^{-9} - 10^{-8}\ M_\odot\ \mathrm{yr}^{-1}$).

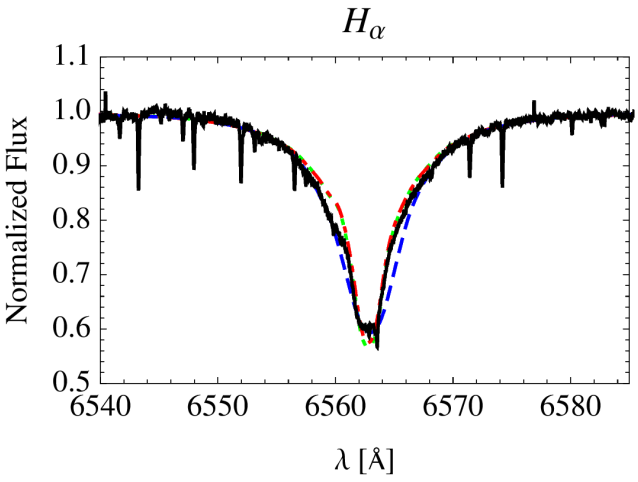

Figure 1. Observed Hα line profile of the weak wind O9V star HD 46202 (black line). Synthetic spectra are shown in red (FASTWIND using solved hydrodynamics from HYDWIND) and blue (CMFGEN using solved hydrodynamics from HYDWIND.

This means that weak winds could be explained in terms of first principles, deserving additional observational constraints. We aim to draw a multi-wavelength picture of weak wind stars by modeling their observed UV, visible and infrared spectra. For this purpose, we have already observed both late O dwarfs and giants in the L-band (enclosing Brα) with the Gemini/GNIRS instrument (λ Ori A, HD

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24431, HD 216898; Gemini period 2023B) and with the ESO/CRIRES instrument (λ Ori A, μ Col, and HD 115455; ESO period P112). We also had allocated time to observe 10 Lac, 68 Cyg, ζ Oph, and HD 193443 with GNIRS (Gemini period 2024A), and ζ Oph, HD 135591, and HD 156292 with CRIRES (ESO period P113).

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An internal view of stellar system Terzan 5

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Keywords: *Galaxy: bulge, globular clusters: individual, open clusters and associations: general, stars: mass-loss, stars: pre-main-sequence*

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We present the spacial-photometric analysis up to 2 arcmin of the globular cluster Terzan 5 using observed with GeMS/GSAOI and HST. Terzan 5 is one of the most interesting stellar systems of the Galactic Bulge. It is one of the most massive globular clusters of the Milky Way, and is really rich in pulsars, besides it is localized near the center of the Galactic bulge. Ferraro et al. (2009) discovered a double horizontal branch (HB), due to two stellar populations that show a substantial difference in age and metallicity ($7Ga$ and 0.5 dex, respectively). Consequently, Terzan 5 together with Liller1, is thought to be one of the few remaining building blocks of the Galactic Bulge. In this work, we determine the spatial distributions of this stellar system.

We used the photometric pipeline SkZpipe (Mauro, 2020) to process GeMS/GSAOI and VVV (Minniti et al., 2010; Saito et al., 2012) data, producing a photometric catalog covering from the center up to the tidal radius. In this work, we show the analysis of the HB populations up to 2 arcmin from the center.

Figure 1 shows how the population associated with the brighter-redder-younger HB is more concentrated near the center than the population associated with the fainter-bluer-older one.

Figure 2 shows the comparison between the cumulative distributions of the two HBs. It confirms that the younger population is centrally more concentrated than the older one, as the multipopulation theory predicts.

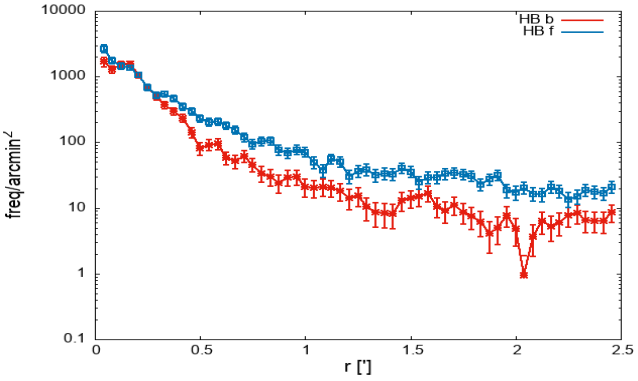

Figure 1. Radial frequency distributions of the redder-brighter and of the bluer-fainter horizontal branches.

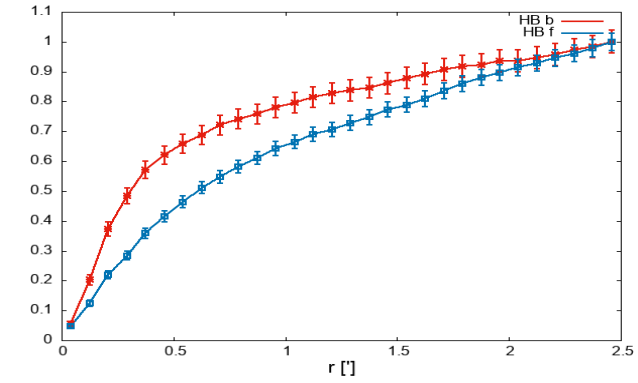

Figure 2. Cumulative distributions of the redder-brighter and of the bluer-fainter horizontal branches.

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Hα emitters in the Magellanic Clouds: searching for Be stars using high-resolution multi-band photometry

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Keywords: *Be, circumstellar matter, galaxies: star clusters: general, stars: emission-line, stars: rotation, techniques: photometric*

Classical Be stars are a subset of main-sequence (MS) B-type stars associated with viscous Keplerian decretion disks responsible for their emission lines. In addition, fast rotation is a fundamental ingredient for the existence of Be stars, as they are by far the fastest among non-degenerate stars. To date, at least three proposed scenarios try to explain the spin-up mechanism and the existence of Be stars: Be stars are born as fast rotators; the spin-up would occur during the evolution of a binary system; or they would start as slow rotators, increasing their rotation throughout their evolution. Even though all mentioned scenarios may play a role in the origin of Be stars, discriminating the relative prevalence of each scenario is a key step towards a better understanding of these objects.

Hα emission is a clear indicator of circumstellar activity in Be stars, historically employed to assess the classical Be star (CBe) population in young open clusters (YOCs). The YOC NGC330 in the Small Magellanic Cloud exhibits a large known fraction of Be stars and was selected for a pilot study to establish a comprehensive methodology for identifying Hα emitters in the Magellanic Clouds, encompassing the entire B-type spectral range. Using the SOAR Adaptative Module Imager (SAMI), we investigated the stellar population of NGC330 using multi-band $BVRI$+Hα imaging (Fig. 1). We identified Hα emitters within the entire V-band range covered by SAMI/SOAR observations ($V \lesssim 22$), comprising the complete B-type stellar population and offering a unique opportunity to explore the Be phenomenon across all spectral sub-classes. The stellar radial distribution shows a clear bimodal pattern between the most massive (B5 or earlier) and the lower-mass main-sequence objects (later than B6) within the cluster. The former is concentrated towards the cluster center (showing a dispersion of $\sigma = 4.26 \pm 0.20$ pc), whereas the latter extends across larger radii ($\sigma = 10.83 \pm 0.65$ pc), indicating mass stratification within NGC330. The total fraction of emitters is $4.4 \pm 0.5\%$, notably smaller than previous estimates from flux- or seeing-limited observations. However, a higher fraction of Hα emitters is observed among higher-mass stars ($32.8 \pm 3.4\%$) than within lower-mass ($4.4 \pm 0.9\%$). Consequently, the putative

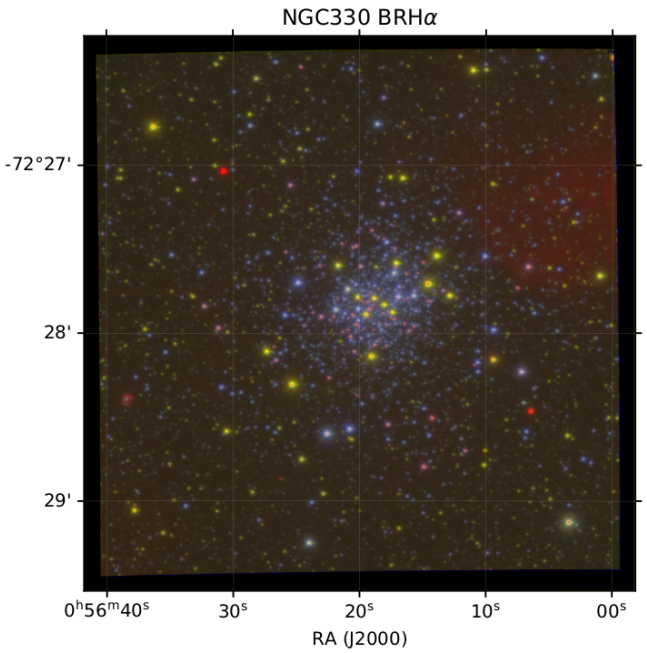

Figure 1. False-color BRHα image of NGC330 (blue: B, green: R, red: Hα) from SOAR/SAMI observations. The image has a 3.1'×3.1' field-of-view, centered at R.A.=00:56:20.0, Decl.=-72:27:51.67 (J2000). North is up, and East is to the left.

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CBe population exhibits distinct dynamical characteristics compared to the bulk of the stellar population in NGC330. These findings highlight the significance of the current observations in providing a complete picture of the CBe population in NGC330.

Combined with the analysis of further YOCs in the Magellanic Clouds, this survey will provide crucial evidence for understanding the Be phenomenon as a function of metallicity and age, putting critical observational constraints on the origin of these massive stellar objects. The complete work will be presented in Navarete et al. (2024).

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Blue straggler stars in open clusters

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Keywords: *binaries: general, blue stragglers, galaxy: open clusters and associations: general*

On this proceeding we present the most homogeneous and large *Gaia* based catalog of Blue and Yellow straggler stars (BSS and YSS) in Galactic open clusters (OCs). We provide valuable information on a handful of clusters, including binary fractions and orbital periods. Additionally, we have investigated potential correlations between the straggler numbers and the structural and dynamical parameters of their parent clusters.

BSS should not exist! However, due to their formation mechanisms, which involve stellar mergers, the collision of stars, and/or mass transfer (MT) from a companion in binary systems, their study contributes to our understanding of stellar and galactic evolution, binary star dynamics, and formation of complex astrophysical systems.

The new list includes 897 BSS and 77 YSS candidates. For all of them we provide positions, colors, proper motions, parallaxes, distance to the cluster center (in arcmin) and membership probability –based on the Gaia astrometric solution (Gaia Collaboration et al., 2018). All relevant information such as methodology, candidate selections, field contamination treatment and main statistical results can be found in Rain et al. (2021).

In addition to the catalog, we conducted three complementary studies summarized as follows:

i) BSS can be used as a tool to determine the dynamical ages of galactic stellar clusters. Thus, here we infer the dynamical state for all OCs in our sample hosting a number of stragglers $N_{BSS} \geq 10$. In general, we found BSS are more centrally concentrated than normal stars in clusters older than 1 Gyr. For all these clusters we computed the A_r^+, an observational parameter that quantifies the level of BSS segregation –see Alessandrini et al. (2016) for more details regarding A_r^+.

ii) Using the Automated Stellar Cluster Analysis `ASteCa` code (Perren et al., 2015) we calculate the binary fraction (N_{bin}) in a handful of clusters. Figure 1 shows the correlation between N_{BSS} and N_{bin}. Here we found a dependence of $N_{BSS} \propto M_{Tot}^{\delta}$ with δ=0.6±0.2. For the first time in OCs, we have quantified and confirmed a correlation between both parameters.

iii) Finally, we conducted a time-series analysis using data from the Transiting Exoplanet Satellite Survey (TESS, Ricker et al., 2015) with a baseline no longer than one month. We identified nearly 70 short-period (SP) binaries, with 90% of them being new discoveries. These binaries exhibit periods ranging from 0.1 to 14 days. Furthermore, we observed that at least ∼7% of the straggler candidates in our sample are part of short-period binary systems. Moreover, our findings indicate that seven clusters exhibit an intriguingly high rate of SP-BSS, surpassing the reported rates in emblematic cases such as NGC 188 and M67, specifically exceeding 10%.

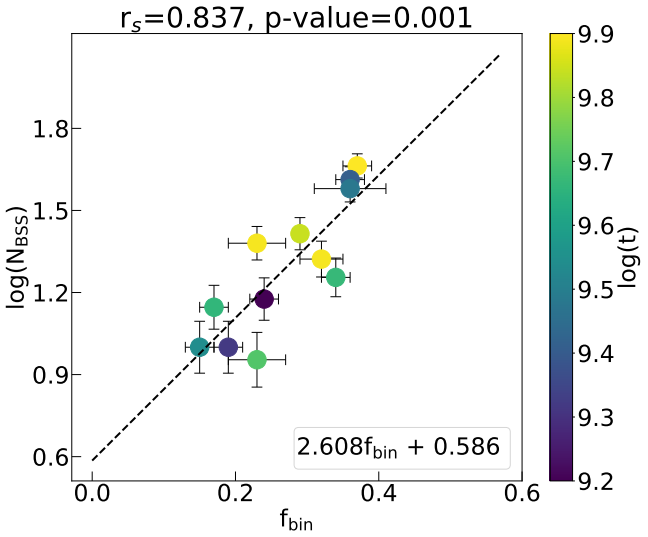

Figure 1. Logarithm of the observed number of BSS as a function of the number of binaries on each cluster. The dashed black line indicates the best fit to the data. Errors are Poissonian.

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Inferring the sub-stellar and stellar initial mass function of nearby young moving groups

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Keywords: *binaries: general, stars: pre-main-sequence*

Based on astrometry and photometry from Gaia Data Release 3 (GDR3), we identified five known Nearby (< 200 pc) Young (< 100 Myr) stellar co-Moving Groups identifying 186 new candidate members. We inferred their Initial Mass Function in the mass range from $0.04 M_\odot$ up to $5 M_\odot$, and considered for recovery and contamination rates. Our preliminary results show that those IMFs are more consistent with a single stellar IMF with characteristic masses around 0.08 $M_\odot$, smaller than the typical 0.2 $M_\odot$ expected for a system-IMF.

The solar neighborhood is populated with Nearby (< 200 pc) Young (< 100 Myr) stellar co-Moving Groups (NYMG; e.g. Torres et al. 2006; Gagné & Faherty 2018; Kerr et al. 2021. Although their origin is a matter of debate, their ages are expected to be one order of magnitude smaller than their dynamical timescales around the Galaxy, supporting the idea of these groups as remnants of stellar populations scattering across the galactic disc.

The NYMGs are ideal candidates for the observational study of the Initial Mass Function (IMF) not only due to their proximity and low extinction but also because their youth guarantees that only their most massive stars have evolved out of the main sequence. This implies that their mass distribution should be similar to their IMF in most of the stellar and sub-stellar mass ranges. However, only a few determinations of the IMF of these groups have been carried out (e.g. Gagné et al. 2017). This is primarily due to the observational challenge posed by their wide spatial distribution, a direct consequence of their proximity, as well as a significant contamination of the samples by field stars.

We used the DBSCAN algorithm on the five-dimensional space of Galactic Cartesian position and tangential velocities in the Local Standard of Rest (LSR) of all the stars from GDR3 (Gaia Collaboration et al., 2023) to identify members from five known NYMGs: β-Pictoris, Tucana-Horologium, TW-Hya, Collinder and PL8.

We used of a model of the Gaia Object Generator (GOG, Antiche et al. 2014) to model the distribution of the field stars in order to quantify the statistical significance of our detection. This synthetic model together with simulated NYMGs allowed us to quantify recovery and contamination rates. Finally, we used Bayesian inference to estimate the masses of both detected and synthetic stars, and to estimate recovery and contamination rates per mass bin. This method led us to a preliminary determination of the IMF for the detected groups in the mass range $0.04 < M/M_\odot < 5$.

We found a total of 186 new candidate members for the studied NYMGs whose membership requires spectroscopic confirmation in future studies. Additionally, we found that the inferred IMFs are more consistent with a single stellar IMF with a characteristic mass close to 0.08 $M_\odot$, smaller than the typical 0.2 $M_\odot$ of a system-IMF.

Improvements in our methods to estimate and correct incompleteness and contamination rates are part of an ongoing project toward a more robust determination of the IMF in several NYMGs.

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Ylgr stellar stream elemental abundances

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Stellar streams are spectacular evidence of satellite disruption, which might originate from globular clusters (GCs) or massive mergers like Sagittarius, Kraken, Sequoia, or Gaia-Sausage-Enceladus (GSE). However, the elemental abundances properties of these objects have been poorly studied. We have obtained near-IR (H-band) high-resolution (R=45000) spectra for four stars in the Ylgr stellar stream with IGRINS/GEMINI spectrograph to obtain elemental chemical abundances for the first time for this stream. Ylgr is a metal-poor group of stars with $\langle$[Fe/H]$\rangle = -1.87$. Additionally, it exhibits depleted carbon and aluminum abundances with respect to the solar values. Despite the small sample, the abundance patterns in the Al-Si, Al-Mg, Ce-Al and Si-Mg planes show a behavior more similar to that of the GSE dwarf galaxy than to clusters. This outcome could indicate a dwarf galaxy progenitor for the Ylgr stellar stream.

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Revised distances for blue horizontal-branch stars based on SDSS photometry

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Stars in the helium-burning phase form a horizontal structure on the colour-magnitude diagram. As they exhibit approximately constant luminosities, the so-called "horizontal-branch stars" can be used as standard candles. In this project, we work with the blue horizontal-branch (BHB) stars, the most metal-poor population in this evolutionary stage, which are excellent objects to explore the outermost regions of the Galaxy. About 5700 BHB stars were found in the sixteenth data release of the Sloan Digital Sky Survey catalogue, selected by photometric and spectroscopic data, and individual probabilities of being a BHB star were assigned based on surface gravity distributions. To determine the photometric distances, we reanalyzed the relation for their absolute magnitude using the *ugriz* system and Gaia distances for globular clusters. We proposed a relation using the colour $(u-r)_0$, besides $(g-r)_0$, to estimate the distances. These new simpler relations present reasonable improvements over previously available ones, especially for stars beyond ∼40 kpc from the Sun. From the distances obtained, inferred ages and the kinematic information available for the BHB stars, we aim to explore the streams found in the Galactic halo and learn more about the formation history of the Galaxy.

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The nature of the enigmatic highly-variable high-mass young stellar object Mol 1: What we know

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Since the discovery (Tapia et al. MNRAS 485, 764, 2019) as a high-mass Class I young stellar object (HMYSO) with large amplitude light variations, Mol 12 (IRAS05373+2349) has been observed extensively. It is at a distance of 1.59 kpc, as determined by VLBI parallax to an associated water maser. This is consistent with a more uncertain Gaia DR3 determination. It is reddened by $A_V > 16$ and has a total luminosity of $1.74 \times 10^3 L_\odot$. SED fitting provides likely stellar, disc, and envelope parameters. Mol 12 drives a bipolar CO outflow that excites a number of nearby shocked knots of molecular hydrogen emission. Light curves of Mol 12 spanning several decades, from red to mid-infrared wavelengths, show a capricious behaviour. It exhibits chaotic variations of more than 5 magnitudes in the J band (1.25 μm), with colour changes that suggest the occurrence of a series of eclipses by dust structures, presumably outliers of the protoplanetary disc. These cause up to 25 V-band magnitudes of extra extinction, in addition to possible changes in accretion luminosity. Medium-resolution spectra from 0.6 to 2.3 μm show numerous emission atomic lines, including C I, N I, Ca II, Mg I, Si I, Fe I, and Fe II, likely originating from the inner zones of the disc. Notably, we detected the He I 1.0830 μm line with a complex P-Cygni profile, indicating the presence of strong inner disc winds accompanied with high accretion. No photospheric absorption lines were found. Strong first overtone CO emission band-heads were detected at 2.3 μm, probably arising in the inner disc. These features, plus the derived total luminosity combined with the presence of associated compact HII region and water maser, lead us to propose that Mol 12 is a Herbig Be star at its earliest phases of detectable life. The observed irregular eclipses are probably caused by dusty fragments of remnant disc material, yet to be modeled. We note that Mol 12 has many of the observed peculiarities with the less luminous T Tauri star RW Aur A.

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Variability in B supergiant stars: a theoretical and photometric approach to pulsation modes and detection of binary systems

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B supergiant stars evolve from O-type stars, however, there is still much uncertainty about their evolution after they leave the main sequence. The asteroseismological study of light curves of massive supergiant stars has revealed that they all pulsate in specific modes, defining regions of instability at the top of the HR diagram. Studying pulsating stars in binary systems is essential for exploring the internal structure of stars and verifying evolutionary models, as they allow the masses of each component to be measured accurately and independently. However, detecting binary systems among evolved B stars is challenging, either because of observational bias or, perhaps, due to the intrinsic variability of the more evolved primary component, leading to light curves and spectra variations. To improve our knowledge of these phenomena, light curves of a sample of massive stars, with L/M ratio ≥ 4, observed with the TESS satellite were studied to determine their periods and quasi-periods, which could be associated with pulsation, binarity, or both. In addition, the pulsation modes were studied based on a linear non-adiabatic model and compared with the observationally detected frequencies, to estimate a theoretical mass for these stars and address the mass discrepancy problem. To obtain a detailed description of the periodic behavior of the signals, two complementary tools were used: the Lomb-Scargle periodogram and the Weighted Wavelet Z-Transform.

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Exploring the uncertainties in mixing processes of low-mass stars: preliminary results

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During the many phases of stellar evolution many different convective zones develop and alter the chemical stratification of the star. Mixing Length Theory (MLT) is commonly used in astrophysics to treat convection and this theory only takes into account convective motions arising from adiabatic perturbations, and usually neglects the impact of chemical gradients (i.e. it usually adopts the Schwarzschild instability criterion). Grossmann et al. proposed a more general theory of convection (from now on GNA) in which the impact both of chemical gradients and thermal diffusion is taken into account. This implies that besides the standard thermally driven convection other regimes, such as, chemically driven convection (Rayleigh–Taylor convection), fingering convection (thermohaline mixing), and semiconvection arise.

Both at the end of helium core burning and during the thermal pulses in the Asymptotic Giant Branch (AGB) a process of stratification takes place in which heavier mixtures are left lying on top of lighter ones. This stratified chemical structure should be unstable either to Rayleigh-Taylor instabilities or the much slower fingering convection.

In this work we explore this mixing processes in stellar models of $3M_{\odot}$ and $1M_{\odot}$ considering both MLT and GNA convection theories. Our work shows that mixing processes induced by negative mean molecular weight gradients, are able to iron out carbon-oxygen (CO) chemical profiles both in the inner and outer CO-core. This happens before the star reaches the end of the AGB. In future works we will expand this exploratory works and assess the impact of these processes on the oscillation frequencies of pulsating pre-white dwarfs.

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Dense gas kinematics in the massive G351.77 protocluster: ALMA-IMF large program observations of N_2H^+

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From the ALMA-IMF Large Program (LP) we got access to the massive filamentary protocluster's observations G351.77, located $\sim$ 2 kpc. We accessed to N_2H^+ line emission of the dense gas, down to $\sim$ 2 kAU resolution. Our main data consists of ALMA observations in the 3 mm spectral band, N_2H^+ line with 7M and 12M arrays, and Total Power (TP) antennas. Moreover, we have used additional data from the LP, such as core catalogs derived from the 1.3 mm band, spectral line fits kinematics of DCN, integrated intensity and mean velocity of H_2CO, and H_2 column density map. To recover the emission, the 7M and 12M arrays were both combined and reduced to then be feathered with TP. The N_2H^+ hyperfine line profile is modeled with PySpecKit, fitting two velocity components, obtaining excitation temperature, optical depth, centroid velocity and line width for each component. In combination with optical depth and the H_2 column density map, we estimated the N_2H^+ relative abundance $\sim (1.66 \pm 0.46) \times 10^{-10}$. Measuring a total H_2 mass $\sim$ 1660 $\pm$ 460 $M_{\odot}$. By examining the Position-Velocity diagrams (PV) at small scales, we observe clear infall signatures (V-shapes) associated with 1.3 mm cores. The most prominent V-shape has an average of mass inflow rate $\sim (4.08 \pm 1.62) \times 10^{-4}$ $M_{\odot}$/yr, and an average timescale $\sim$ 21 $\pm$ 1.7 kyr. The PV on large scales shows two clear filamentary structures in N_2H^+ separated both in space and velocity. H_2CO and DCN cover most central regions, where there is no N_2H^+ emission. They provide additional information on the central part of the protocluster, whose PV shows signatures of rotation and infall, being consistent with the N_2H^+ velocities of the PV at large scales.

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Dynamos in partially convective M dwarfs

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M dwarfs are low-mass main-sequence stars, which are the most common type of star in the galaxy. It is well known that they have significant magnetic activity but the mechanism that controls this is still unclear. M dwarfs more massive than 0.35 $M_\odot$ are partially convective, and this transition marks an important change in stellar structure that can affect the production and storage of internal magnetic fields. The aim of this work is to test a new computational model for the dynamo of partially convective M dwarfs. This model consists of three-dimensional magnetohydrodynamical (MHD) numerical simulations using the star-in-a-box model, where we consider a star of radius R in a Cartesian cube of size $(2.2R)^3$. Within this model, we change the magnetic boundary condition to see how this affects the dynamo and also explore different rotation rates. Up to now, we have observed clear cycles in three of our simulations with different rotation rates, while the others have dynamos that are quasi-static. In addition, we present an exceptional case where the magnetic field disappears and reappears. Furthermore, we found that $P_{\rm rot}/P_{\rm cyc} \propto {\rm Co}^{\beta}$ with $\beta = -1.15 \pm 0.17$ that is consistent with earlier studies where $\beta < 0$ was found for global simulations of solar-type stars.

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Core dynamo simulations of A-type stars

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Early-type stars have convective cores due to a steep temperature gradient produced by the CNO cycle. One of the subclasses of these stars is the chemically peculiar Ap and Bp stars, which host large-scale magnetic fields in the range of 200 G to 34 kG. Two of the hypotheses to explain these fields are the fossil field theory and the core dynamo theory. We performed 3D numerical simulations of a $2M_\odot$ A-type star with a convective core of roughly 20% of the stellar radius surrounded by a radiative envelope, using the star-in-a-box model as a way to explore magnetic fields driven by convection in the core of the star. The non-ideal fully compressible magnetohydrodynamics equations were solved using the PENCIL CODE. We explored rotation periods from 8 to 20 days, and these simulations were divided into two sets: Whole star models and a zoom set, where 50% of the radius is retained. Both sets allow us to have a better understanding of the core dynamo, differential rotation, and also the magnetism at the surface of the star. We conclude that the core is able to host very strong hemispheric dynamos, with toroidal magnetic fields up to 200 kG. Nevertheless, only a very small fraction of the magnetic energy is able to reach the surface, which is not enough to explain the observations.

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Evolution in low mass close binaries with a black hole: the cases of V404 Cygni and V381 Normae

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When the components of a binary system are close enough, one can fill its Roche lobe and start transferring mass to the companion. These mass transfer episodes affect the whole evolution of the star, being a completely different situation as if it were isolated. In this work, we study two systems with these characteristics, with the particularity that the accreting object is a black hole (BH) on both. We chose V404 Cyg as one of our study targets due to its well-measured fundamental parameters, including mass transfer rates and theoretical estimations, along with an observational estimation of the BH spin parameter, which is notably high. On the other hand, we also investigated V308 Normae, a system with similar known parameters that stands out as the only system with a moderate and highly confident BH spin parameter, measured consistently using different techniques. With the help of our binary evolution code, we developed evolutionary models to obtain a progenitor for each system, considering the initial moment when the star is on the zero-age main sequence, and the BH is already formed. These models allow us not only to study the entire evolution of the donor star for each system but also to derive constraints on mass transfer episodes, orbital evolution, and changes in the BH spin due to accretion.

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A LAMOST spectroscopic study of T Tauri Stars in the Orion OB1a sub-association

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We present a spectroscopic analysis of T Tauri stars (TTS) observed with the wide-field multi-fiber spectrograph LAMOST in the substellar associations Ori OB1a located in the Orion Star-Forming Complex. Based on GAIA-DR3 data, we selected stars with proper motions and parallaxes expected for TTS belonging to the young association. We perform a spectroscopic analysis to obtain spectral types and measure equivalent widths of Li I and Hα to confirm the youth of the stars and estimate the accretion status. We also estimate extinctions, masses, and ages for the studied sample. Out of 342 TTS with spectroscopic and kinematic properties to be members of the sub-association, 12 are reported here for the first time. Finally, we detect four stellar kinematic groups located at different distances, two in the north field and two in the south field. These groups also show different proper motions. This suggests that the star-forming scenario in this region is more complex than the traditional spatial-temporal scenario, in which a generation of stars triggers the formation of a new spatially differentiated generation of stars. This work was published in the Astronomical Journal (Bibcode: 2023AJ....165..205H).

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O Vz stars in low-metallicity environments in the Magellanic Clouds

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Massive stars are powerful "cosmic engines" that modify the morphology, chemistry and dynamics of their host galaxies, playing a fundamental role in the Universe. They are found in distant and highly extinguished regions, so our understanding of their formation and evolution is still limited. The morphological and quantitative study of their optical spectra is a powerful tool for determining their properties. In this work, we focus on stars of the O Vz class, identified by presenting a He II λ 4686 absorption much stronger than expected. It has been suggested that these objects are on, or very close to, the Zero-Age Main Sequence (ZAMS), so studying them can provide key information about the massive star formation process.

The "z phenomenon" has been investigated in the Galaxy, but there are no systematic studies in environments with different metallicity. Using high and intermediate-resolution optical spectra obtained at the VLT and LCO observatories (Chile), we are carrying out a comparative study of O Vz stars belonging to two star-forming regions in the Magellanic Clouds: 30 Doradus in the LMC and NGC 346 in the SMC, along with a star-forming region in the Milky Way: NGC 3603. Here, we present the preliminary results of our analysis, which provide clues about the role of metallicity and other parameters in the development of the z spectral feature.

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Exploring the hierarchical formation of the Milky Way with hypervelocity stars

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The exploration of the outer halo of the Milky Way, through wide-sky photometric and spectroscopic surveys, has unequivocally confirmed that our Galaxy has formed as a result of the continuous merger of protogalactic fragments, aligning with predictions from cosmological Lambda-Cold Dark Matter simulations. Here, we discuss the hypervelocity stars, considered potential remnants of past accretion events, with velocities exceeding the local escape speed. Alternatively, hypervelocity stars may arise from binary system disruptions during close encounters with the supermassive black hole at the center of the Milky Way. Thanks to the invaluable data provided by Gaia, we have successfully identified stars exhibiting a high likelihood of belonging to this intriguing stellar family. Follow-up VLT spectroscopy has allowed us to estimate their total velocities, which, in certain cases, reach values of up to 1200 km/s. By reconstructing their past orbits, we have uncovered evidence suggesting that some of these stars might have originated within a now-disrupted dwarf galaxy or experienced another violent event far from the Galactic center.

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New evidence for a black hole in the X-ray binary system Swift J1910.2−0546

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Swift J1910.2−0546 is a transient X-ray binary discovered in 2012 when the system was detected in an outburst episode. During that state, it showed the typical behaviour found in systems harbouring black holes although the nature of the compact object has not been established since. In this contribution, we show a comprehensive study of *Swift* J1910.2−0546 using optical outburst (obtained with the INT and NOT) and quiescence data (obtained with GTC and VLT), obtaining that the donor star is later than ∼G2 V. We also establish constraints to the orbital period (< 8.7 h) and distance (> 4.6 kpc) which, together with the lack of double peak emission lines (suggesting an inclination < 35 deg) and the radial velocity estimates obtained from the Hα line in quiescence, support the presence of a black hole in the system.

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The own survey: What we can tell about massive binaries after 18 years of systematic observations

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The OWN Survey (Barbá et al. 2017, IAUS, 329, 89) is a high- resolution spectroscopic survey of Galactic massive stars accessible from the Southern hemisphere. It has been carried out since 2005, using echelle spec- trographs at 2-m class telescopes in Chile and Ar- gentina. More than two hundred stars of types O and WN have been monitored to assess their multi- plicity status through the systematic study of their radial velocities. About two thirds of the sample were found to show RV variations. The main result of the OWN is the discovery of more than 60 multiple systems (37 SB2, 19 SB1 and 6 SB3), effectively doubling the volume of knowl- edge previously existing about massive stars multi- plicity. The RV orbits of many of them were accurately determined. Additionally the detection of spectroscopic variability in some objects has allowed insights into magnetic fields, circumstellar material and interactions between components. Individual key objects were thoroughly studied. Remarkable examples are the ZAMS triple system Herschel 36A (Campillay et al. 2019, MNRAS, 484, 2137), the long period binary HD 54662 (Barbá et al. 2020, MNRAS, 494, 3937) and WR21a (Barbá et al. 2022, MNRAS, 516, 1149), which is one of the most massive stars in the Milky Way. Thanks to the contribution of the OWN Survey, a significant pool of spectroscopic orbits is now available for statistical analysis. The distribution of orbital elements (period, eccentricity, and mass ratio) for different luminosity classes is be- ing investigated, shedding light on the formation and evolution of these systems (Gamen et al. in prep.).

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Cepheid pulsation mode identification via unsupervised machine learning

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In this work we aim to determine the pulsation mode of a Cepheid variable star, only considering extinction and distance-free features of its light curve, and without the use of Fourier parameters, as is custom in the literature. We developed a set of features calculated by a continuous model of the light curve, namely the phases and curvature of the extrema points, the phases and values of the derivative extrema, the phases of the rising and falling branches, the amplitude, and the period. These features are meant to be used on a clustering algorithm in order to identify the pulsation modes.

As our test case, and motivated by the importance of the Magellanic Cepheids in the calibration of the extragalactic distance ladder, we calculated these features on the Galactic and LMC Cepheids from the OGLE Catalog of Variable Stars, from both version III and IV, totaling to 12482 objects. We then fed the feature dataset to the HDBSCAN algorithm, playing with the minimum cluster size, and using the Chebyshev metric. The desired level of detail was achieved with a minimum cluster size of 5, and a hybrid ϵ hyperparameter of 0.047, giving a 29% of data being classified as noise.

Our clustering correctly separated the fundamental, first, and second overtones on the Classical Cepheids, along with the anomalous and type II Cepheid types. There is some confusion, however, between the WVir and fundamental Cepheids, and general mixing among the type II subclasses. Moreover, the clustering algorithm identified different substructures within the established fundamental and first overtone modes. These could be a hint to a richer morphology of the classical Cepheid light curves, perhaps related to the Hertzprung progression, that will be explored in future research.

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Determination of fundamental parameters of Wolf-Rayet stars in eclipsing binary systems

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Despite the essential role of massive stars in the evolution of the Universe, our understanding remains incomplete, particularly concerning mass loss and its influence on post-main-sequence evolution. Recognizing binary stars as ideal benchmarks for determining stellar parameters, we focused on two WR+O systems, WR 62a and WR 68a, identified as double eclipsing systems through TESS photometry. Notably, the light curve of these binaries presents a challenge to the classical modeling of photospheric eclipses, as demonstrated by the limitations of the PHysics Of Eclipsing Binaries (PHOEBE) code.

To address this, we extended our approach by incorporating a model of Thomson scattering for atmospheric eclipses, complementing PHOEBE. Furthermore, a custom light curve synthesis algorithm was employed to account for binaries with extended atmospheres. This comprehensive methodology, integrating TESS data and radial velocity curves, significantly improves parameter precision, facilitating the analysis of the masses and radii of the WR and O components within the framework of massive stellar evolution.

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Internal structure of open clusters with close companions

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Our project aims to analyze the alteration and evolution of the internal structure of open clusters that are part of a binary or multiple systems. For this, we have assembled a homogeneous sample of open clusters, comprising both single and multiple systems, with membership probabilities of stars within these clusters obtained from previous catalogs, using Gaia astrometric and photometric databases. To quantify the structural parameters of the clusters in our sample, we employ the "minimum spanning tree" technique, which allows us to gain valuable insights into the cluster's internal structure. As the main results, we found the Q value is more affected by the dynamic state of multiple open clusters than by single ones. This could explained as the gravitational interaction between the linked clusters amplifies the effects of dynamic evolution. These mainly affect its peripheral regions and appreciably less its central regions. On the other hand, it does not significantly affect the most massive stars. The employed simulations indicate that a low fractal dimension tends to result in the creation of multiple components. It is highly likely that most of these systems are identified as binary ones, but they could be triple or even multiple systems. Finally, the average Q parameter of the entire binary/multiple systems is lower than the parameters of each component. This suggests that they do not inherit the original fractal dimension value.

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Unveiling the evolutionary states of B supergiant stars

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Massive stars are the cornerstone for the chemical evolution of the interstellar medium through feedback from their winds and supernova explosions. Through a synergy between asteroseismology, evolutionary modeling, and spectroscopic analysis, new insight into the evolutionary stage of three well-known B supergiant stars was achieved: HD 42087 (PU Gem), HD 52089 (ϵ CMa), and HD 58350 (η CMa). For our analysis, we used the 2-min cadence TESS data to study the photometric variability and obtained new spectroscopic observations at the CASLEO observatory. We used non-LTE radiative transfer models calculated with CMFGEN. These models were included in the iterative spectral analysis pipeline XTGRID to determine their CNO abundances and their stellar and wind parameters, which were later compared with Geneva evolutionary tracks. Based on the abundance ratio alone, we found that all our stars are more consistent with a pre-RSG stage. However, stellar evolution models confirm this stage only for HD 42087 and HD 52089, considering their derived T_{eff}, L and M, while predicting HD 58350 to be at the post-RSG stage. The results underscore the need to study large samples of B supergiants homogeneously and to review processes involved during the evolution of massive stars, such as mass loss via stellar oscillations.

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Exploring star cluster through eclipsing binary members

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Binary stars constitute approximately 70% of stellar populations. Particularly, those within star clusters play a crucial role in understanding various aspects of stellar astrophysics. In this study, we conducted an extensive investigation of eclipsing binary (EB) candidates in a specific near-infrared window in the southern part of the disk of the VVV Survey. Our primary focus is to explore the potential membership of these binaries within star clusters in the same region. By analyzing Gaia DR3 and VVV databases, we thoroughly examined two open clusters, Teutsch 77 and Ruprecht 97, each associated with two EBs in total, among the VVV and ASASSN dataset. We modeled with PHOEBE code the light curves, in the V magnitude, of the two new ASASSN binaries. We analyze the kinematics and photometry of the studied open clusters, aiming to uncover any possible connections with the identified EBs. This work presents our preliminary findings on cluster membership and characterizations, providing crucial insights into the intricate interplay between binary systems and star clusters.

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Atlas of massive galactic O-type spectral standards in the near-infrared

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The study of spectral morphology is a powerful tool for understanding the fundamental properties of stars. The spectral classification scheme for O stars has been revised in the context of the Galactic O-Star Spectroscopic Survey and a new set of spectral standard stars has been proposed. Since the vast majority of the Galactic O stars are visible only in the infrared due to large interstellar absorption in the optical, it is necessary to extend this work towards those wavelengths.

We are working on the construction of an atlas of Massive Galactic O-type Spectral Standards in the near-infrared (MaGOSS in the NIR), observing the standards, defined in the last installment of the Galactic O-Star Spectroscopic Survey, with high-quality spectra in the wavelength range between 0.85 μm and 2.5 μm.

We present here an advance of the Atlas of MaGOSS in the NIR, which includes spectra of a sequence of dwarf, giant and supergiant stars. We analyze this data set to establish some spectral characteristics of such stars, with the aim of defining classification criteria in the near-infrared range, such as the ratios HeI λ1.700 μm/HeII λ1.692 μm, HeI λ1.031 μm/HeII λ1.042 μm, and HeI λ2.112 μm/HeII λ2.189 μm.

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Supernova light curves with the HSH telescope at CASLEO

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The early-time light curves of Supernovae (SNe) are crucial to know the properties of their progenitors, such as radius and density profile. For this purpose, observations are fundamental to obtain images as soon as possible. In this work, we present the first observing campaign by the SOS (Supernova Observations and Simulations) group using the 60 cm Helen Sawyer Hogg (HSH) telescope at CASLEO, Argentina. The campaign had the following goals: test the capabilities of the instrument to perform very early follow-up observations of SNe ; obtain photometry of transients within hours/days from discovery; and obtain *BVRI* light curves of selected SNe.

The campaign lasted 37 consecutive nights, where 70 transients were observed. From these, 27 (∼39%) were confirmed as SNe, being 17 Type Ia, 2 Type Ib/c, 2 Type Ic and 6 Type II. For 5 of them, the SOS group made 3 announcements with the early discovery confirmations. The mean delay between discovery and our first observation was 31 hours. The average image quality at FWHM was 3.4 arcsec, and this may have been affected by seeing, focus and tracking problems. In addition, by the analysis of the light curves of 3 Type Ia SNe of our sample that had more than 15 epochs, we estimated the Δm_{15} parameter, the distance to their host galaxy and the reddening of the host. The luminosity distances agreed within ∼13% with those based on the redshift.

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The IMF in Orion OB1b from $0.05M_\odot$ to $8M_\odot$ using public surveys

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The initial mass function (IMF) is one of the main results of the star formation process and a fundamental quantity for many branches of astrophysics. The Orion complex is one of the most studied star-forming regions composed of several sub-regions including stars and brown dwarfs in a wide mass range, with ages spanning from $\sim$ 1 to $\sim$ 10 Myr and distances around 400 pc. Particularly, the slightly evolved populations such as 25 Ori in Orion OB1a, σ Ori in Orion OB1b and Collinder 69 in λ Ori also show low extinctions which makes them a perfect laboratory for robust determinations of the IMF from massive stars down to the planetary mass domain. In this work, we determine the system IMF of stellar and sub-stellar overdensities belonging to the Orion OB1b sub-region in a mass range from $0.05M_\odot$ to $8M_\odot$. The candidate members were selected independently for different stellar mass ranges according to their distribution in color-magnitude diagrams and/or kinematics diagrams made based on Pan-STARRS DR1 photometry and Gaia DR3 photometry, proper motions, parallaxes and radial velocities. Additionally, we corrected the resulting distributions by the expected contamination from field stars and the biases affecting the observable quantities, using spectroscopically confirmed members from the literature as a control sample. We present the comparison of the resulting IMF with those previously known for other Orion sub-regions, focusing on the similarities of the IMF in the solar neighborhood and the predictions from low-mass stars and brown dwarf formation models.

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Project SOL (Solar Origin and Life): Detailed characterization of candidates at ZAMS and Subgiant stages

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The solar situation in the galactic neighborhood is not well understood, especially when we compare its physical properties (atmospheric parameters, evolutionary parameters, chemical composition, magnetic activity, among others) with those of nearby stars. Thereby, we still can not fully understand if the Sun is a typical star or not. This happens because recent results in the literature support both hypotheses. Therefore, this work aims to identify and characterize stars with evolutionary tracks similar to the Sun (solar mass and metallicity) that could represent it at the ZAMS and subgiant stages. Thus, we performed a precise spectroscopic analysis of the candidates using high resolution (R $\approx$ 35000 - 115000) and signal-to-noise (S/N $\geq$ 150) spectra obtained with modern instruments on different telescopes around the world. We adopted the classical spectroscopic method, which uses equivalent widths of Fe I and Fe II lines and is based on the excitation and ionization equilibria. Additionally, we derived mass, radius, luminosity and age, using theoretical evolutionary tracks and isochrones, and kinematic parameters for all stars in our sample. We also performed age estimates through 2 additional independent methods and we present the chromospheric activity levels of our candidates. From these, we identified 2 candidates (HD 13531 and HD 61033) and 1 candidate (HD 148577) capable of representing the Sun at the ZAMS and subgiant stages, respectively. Moreover, 2 stars (HD 64114 and HD 197210) could be interesting for studying the Sun with $\approx$ 2 Gyr, when the Earth's atmosphere started having a significant amount of oxygen. Although our sample is not big enough for us to answer if the Sun is typical or not, it shows we are able to identify stars similar to our own at different evolutionary stages, which is very important for the search for exoplanets and habitability studies.

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Studying supernovae associated with long gamma-ray bursts

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The origin of stellar explosions associated with long-duration gamma-ray bursts (GRB SNe) is an intriguing open topic in the field of stellar astrophysics of massive stars. In all cases, these supernovae (SNe) were classified as type Ic-BL, indicating Hydrogen and Helium deficiency, and showing broad lines in their spectra. This last characteristic is indicative of high velocities and energies. In this work we thoroughly analyze the physical properties of a selected sample of GRB SNe, contrasting them with those derived for other groups of SNe. The use of varying methods in previous studies to calculate bolometric luminosities hindered comparisons between objects. To ensure comparability, we standardized the calculation method for bolometric luminosities in our sample. Subsequently, we model the objects using a hydrodynamic code and derive their physical parameters. To conclude, we compare our results with those obtained for stripped-envelope SNe and SNe Ic-BL lacking a detected GRB available in the literature. Our findings reveal the existence of two possible solutions: low-mass models or high-mass models, the latter necessitating larger compact remnants consistent with black hole formation. Both solutions require the common characteristic of a small ejected mass to reproduce the observations.

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Inferring the production rate of intermediate-age RR Lyrae stars using Magellanic Clusters

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RR Lyrae stars (RRLs) are vital in establishing the cosmic distance ladder due to the relations they follow between their luminosities, metallicities, and pulsation periods. RRLs have been historically considered as tracers of old populations (older than 10 Gyr). However, recent studies in the field of the Milky Way and Magellanic Clouds suggest the existence of RRLs in intermediate-age populations (1-8 Gyr), challenging our understanding as they cannot be accounted for by stellar evolution models of isolated stars, making binary evolution the prime suspect to explain their existence. Our goal is to look for direct evidence of the existence of these stars by looking for RRLs in intermediate-age clusters. To this aim, we establish an inference model intended to estimate the membership probability of RRLs from the Gaia DR3 and OGLE catalogs to massive intermediate-age stellar clusters in the Large and Small Magellanic Clouds. Because the expected rate of production of these stars in any individual cluster is expected to be small, we combine the data for many clusters to infer the production rate of RRLs per unit mass in a given age range. We obtain a production rate of ∼10 RRLs per $10^5\,M_\odot$ for old clusters (>8 Gyr), in accordance with observations in Milky Way globular clusters, and infer a rate of $\leq$ 2 RRLs per $10^5\,M_\odot$ for intermediate-age (1-8 Gyr) clusters. Our method also allows us to build a list of RRLs with a high membership probability to intermediate-age clusters, which will require spectroscopic follow-up to confirm their membership to the clusters.

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Close binary systems: evolution and environment

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Binary stars are very important in Astronomy. In some cases, it is possible to access, with good precision, the fundamental parameter that determines the evolution of an isolated star: its mass. In close binary systems, if close enough to each other, the evolution of the components changes completely compared to what each of them would have had in isolation, because mass loss may occur by Roche lobe overflow. Examples of objects due to binary evolution are low-mass helium white dwarfs, type Ia supernova progenitors, cataclysmic variables, black widows and redbacks families, blue and yellow stragglers. In addition to the two stellar components, there is another fundamental actor: the accretion disk. Accretion disks have been studied for decades. However, the complexity of the physical processes that occur in it means that we still have a lot to explore. In this poster, we will make a brief description of the evolution of close binary systems composed of a low-mass normal star and a neutron star, using models obtained from our binary evolution code. We show the method we use to search for a possible progenitor of PSR J1622-0315, a redback whose characteristic parameters have been recently determined. Subsequently, we describe the thin disk treatment ("alpha disk"), where it is possible to decouple the vertical from the radial treatment (where temporal evolution is found). We present our first results and discuss the steps to follow to study the effect of neutron star irradiation on the accretion disk.

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Ca triplet metallicities and velocities for 12 globular clusters toward the galactic bulge

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We used near infrared low resolution spectroscopy with the FORS2 instrument on the VLT to measure the equivalent widths of the CaII triplet (CaT) lines for a number of stars per cluster. We derived radial velocities, ascertained membership, and applied known calibrations to determine metallicities for cluster members, for a mean of 11 members per cluster. We derive mean cluster RV values to 3 km/s, and mean metallicities to 0.05 dex. We find general good agreement with previous determinations for both metallicity and velocity. On average, our metallicities are 0.07 dex more metal rich than those of Harris (2010, arXiv:1012.3224), with a standard deviation of the difference of 0.25 dex. Our sample has metallicities between -0.21 and -1.64, and the values are distributed between the traditional metal rich BGC peak near [Fe/H] -0.5 and a more metal-poor peak around [Fe/H] -1.1, which has recently been identified. These latter are candidates for the oldest GCs in the Galaxy, if blue horizontal branches are present, and include BH 261, NGC 6401, NGC 6540, NGC 6642, and Terzan 9. Finally, Terzan 10 is even more metal poor. However, dynamically, Terzan 10 is likely an intruder from the halo, possibly associated with the Gaia-Enceladus or Kraken accretion events. Terzan 10 is also confirmed as an Oosterhoff type II GC based on our results.

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Recharacterization of open clusters in optical and near-infrared wavelengths using machine learning methods

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In recent years, there has been a major revolution in the open clusters field. With the numerous attempts to characterize them using different techniques and clustering models in the optical and infrared domain, we currently have a mixture of results that make it challenging to analyze the true structure of certain clusters and understand their evolutionary history. We propose implementing a single method, an artificial neural network, with members from different methodologies and wavelengths. Initially, we selected one cluster: NGC6259 using optical/infrared photometric and astrometric data from Gaia DR3 and VVV/VIRAC2 surveys. The selected cluster has a particular "blob" in the reddest part of its stellar sequence. After re-identification, I will present the preliminary results on the revisited cluster sequence on different parameter spaces, its radial velocity and distance distributions, age assessment, and cluster radial profile. Complementary, with the study of the available spectroscopic information of some of the cluster members, we expect to shed light on the real nature of the "blob" on the cluster sequence. In this contribution, I will also discuss how the results contribute to the possibility of establishing a cluster membership assessment that mixes different machine learning methods.

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Small-scale substructures in Taurus transition disks around low mass stars

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The process of planet formation and disk evolution leaves an imprint on the material that surrounds a young star. Imaging from at high spatial resolution has revealed that most protoplanetary disks host small-scale (few au) substructures. While rings and gaps are very frequent, asymmetric features and spiral arms are also present. At low-resolution annular features are detected in disks around young stars with a wide range of stellar properties, from very low mass stars to Herbig AeBe stars, suggesting that rings and gaps may be ubiquitous and comprise key processes of the star/disk evolution. The analysis of high-contrast rings shows that these prominent rings are consistent with dust trapping, enabling the accumulation of dust grains in these regions and favoring their growth towards planetesimals. Therefore, small-scale substructures in disks play a crucial part in the planet formation process. Our methodology consists on using deep (20 μJy/beam) - high spatial resolution (down to 42 mas) - dust continuum observations at 1.3 mm with ALMA to target 5 transition disks located in the young, nearby, Taurus star-forming region. So far, we have found evidence for small-scale substructures in the outer disk rings of the sample made up solely of disks around low-mass stars. Fitting the visibilities we have measured the shape location, width, contrast, and optical depth of the outer disk features, including non-axisymmetric structures such as spirals and arcs. Our aim is to compare these properties to that of known substructures in higher mass stars and constrain the degree of dust trapping in rings or asymmetric features associated with signatures of planet formation for a wide range of stellar parameters.

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Uncovering variable stars in Ultra Faint Dwarves without filter

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Several satellites of our Milky Way have been discovered in the last decades. Most of them could not be found before due to their extremely low luminosity, now known as Dwarf Spheroidals (dSphs) and Ultra faint dwarfs (UFDs). These systems are most dominated by dark matter, and they are key to explore a large variety of topics. Unfortunately, most UFDs are not suitable for extensive analysis due to the scarcity of bright stars. The available color-magnitude diagrams (CMD) of these systems are poorly populated and do not reach the sub-giant branch level in most cases. Their key parameters are thus derived from isochrone fits that are uncertain and degenerate in the three input parameters of age, metallicity, and distance. Our principal aim is to detect RR-Lyrae variable stars, which have been found in all dSphs studied so far. In fact, their well-known period-luminosity relation makes them ideal distance indicators for old stellar populations. The discovery of even one such star would fix the distance much better than what can be done through isochrone fit, improving measures such as luminosity and size, and allowing a better estimate of age and metallicity, among other benefits. We are probing a new method to detect the RR-Lyrae stars of the UFDs that is to observe them directly, without any filter. Our aim is to successfully deal with all the issues that involve using this method to detect variable stars, such as the lack of standard stars, leading to magnitude dependencies in color and/or airmass, among others. If we are successful, we will be able to find variable stars in UFDs using only a 1-m telescope, giving new life to these increasingly forgotten telescopes. Using only images from the 1-meter Swope telescope (LCO) we found in Reticulum II a variable star already identified by the Gaia survey. Now we are studying Grus II to find similar results.

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TESS survey for magnetic white dwarfs in symbiotic binaries

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Symbiotic stars are a subclass of interacting binary systems where a compact object, typically a white dwarf (WD) or a neutron star, accretes material from an evolved giant. Accretion can occur through two primary mechanisms: wind accretion or Roche lobe overflow. Wind accretion is the dominant mechanism in most symbiotic stars, but in a small fraction of symbiotic stars, Roche lobe overflow can also occur. Typical orbital periods of symbiotic stars are observed over relatively long timescales ranging from hundreds of days to decades. Shorter time-scale variability is also observed in these systems. This short- term variability in symbiotics is related to the accretion process and the formation of the accretion disk, whichis crucial for understanding the evolution of these systems. The detection of periodic modulations in the optical light curves of symbiotic binaries provides evidence for the presence of magnetic white dwarfs, which plays an important role in the accretion process by truncating the accretion disk and regulating the accretion flow. We propose to do a survey with TESS of symbiotic systems to find new candidate magnetic WD in symbiotics.

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The XshootU Stellar Library: Hot low metallicity stars

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Stellar spectral libraries are one of the main ingredients of stellar population models. They can be either empirical or theoretical. Empirical libraries are based on observations, meaning that all features in models generated with them will be real. The disadvantage is that it will always be limited by the stars we can observe. Theoretical libraries do not have this setback and stellar spectra can be generated with any atmospheric parameters desired. However, models are based on approximations and simplifications, and therefore not quite yet able to reproduce all features of real stellar spectra. That is why, despite the existence of several empirical libraries, there are still efforts to push their boundaries. One of the major deficiencies of the empirical libraries available today is the coverage of hot/young stars and low metallicity. In this work, we present the XShootU stellar library, the most recent effort to try to fill this gap. The ULLYSES program (HST) generated a UV spectroscopic library of 160 massive stars in the LMC and the SMC, uniformly sampling the parameter space of spectral type and luminosity class for massive OB stars. In parallel to ULLYSES, XShootU is collecting high S/N spectra with R∼10,000 over the spectral range from 300 nm to 2.5 microns of these stars. This will vastly extend the power of ULLYSES spectra by merging the UV, optical, and NIR. ULLYSES + XShootU is by far the most complete, highest-S/N, and highest resolution library of hot, massive stars with the broadest spectral coverage. In combination with other stellar libraries available in the literature, XshootU will allow self-consistent population synthesis models of systems hosting both young and old stars.

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The morpho-kinematic structure of the Thor's Helmet Nebula

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Around some Wolf-Rayet (WR) stars we found gas and dust whose presence is associated directly with the central star. Often, these materials present patterns and structures in a variety of shapes (Toala et. al. 2015; A&A, 578, A66). In this context, an object with striking features is NGC 2359 (Thor's Helmet), whose complex and intricate filamentary sharp structure, is composed of a large shell of gas and dust that surrounds the central star. In order to obtain important insights into their dynamic formation and structure we have obtained high dispersion spectroscopy of the main nebula to investigate the kinematics and the complex processes that occur in the final stages of this massive star life. We present a morpho-kinematic study of the WR nebula NGC 2359 around the WR7 star through high-resolution Manchester Echelle Spectrograph (MES) observations using the 2.1m telescope at the Observatorio Astronómico Nacional (OAN) Mexico. A total of 26 long-slit positions were used. The long-slit high-dispersion optical spectroscopy of NGC 2359 was acquired in 2020, 2021 and 2022 using filters covering the spectral range that includes the Hα, [N II] and [O III] lines. We found that the kinematics of this WR nebulae are highly complex, with a variety of structures and velocities. The nucleus of NGC 2359 resembles an interstellar bubble, produced from the interaction between a fast wind originated from a massive WR central star that is surrounded by an enormous HII region (Sharpless 298) within a molecular cloud. The wind is responsible for compress the medium, producing the bubble of gas around the star. We found that our initial shape model resembles that for a cloud-cloud collision. The O-type central star will evolve into the WR star with a wind-blown bubble such as NGC 2359.

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From Post-AGBs to white dwarfs: Exploring the fascinating evolution of intermediate mass stars (Invited contribution)

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Keywords: *ISM: abundances, ISM: jets and outflows, ISM: kinematics and dynamics, planetary nebulae, stars: AGB and post-AGB, white dwarfs*

Abstract

I will present insights from recent studies regarding the evolution of intermediate-mass stars, focusing specifically on the transition from the post-AGB phase to the white dwarf stage. These investigations provide fresh perspectives on these captivating astronomical objects. Throughout this evolutionary path, intermediate-mass stars experience intricate physical and chemical transformations, leading to notable alterations in their characteristics. I will present observational and theoretical findings crucial for enhancing our comprehension of the life cycle of intermediate-mass stars, exploring their role in enriching the Universe chemically. Additionally, I will highlight unresolved questions that warrant further investigation.

Resumen

Presentaré perspectivas provenientes de estudios recientes acerca de la evolución de estrellas de masa intermedia, centrándome específicamente en la transición desde la fase post-AGB hasta la etapa de enana blanca. Estas investigaciones ofrecen nuevas visiones sobre estos cautivadores objetos astronómicos. A lo largo de este camino evolutivo, las estrellas de masa intermedia experimentan intrincadas transformaciones físicas y químicas, lo que conlleva alteraciones notables en sus características. Presentaré hallazgos observacionales y teóricos cruciales para mejorar nuestra comprensión del ciclo de vida de las estrellas de masa intermedia, explorando su papel en enriquecer químicamente el Universo. Además, destacaré preguntas sin resolver que merecen una investigación más detallada.

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1. Introduction

In this review, I will be discussing the fate of stars with initial mass (M_{ZAMS}) comprised between ∼1 and 8 M⊙, after their evolution on the Main sequence, Red Giant and Asymptotic Giant Branch (AGB) sequences. Post-AGB stars (PAGBs) mark the conclusion of the AGB evolution, distinguished by relatively high mass loss events (10^{-7}–10^{-4} M⊙/yr). These stars display a characteristic (mid-)IR excess and as they transition to higher effective temperatures, they maintain roughly constant luminosity. Nevertheless, they have not reached the temperature necessary to completely ionise the surrounding circumstellar material. The visibility of the central star depends on the opacity of the circumstellar shell, determining whether it is exposed or remains embedded (van Winckel, 2003). The entrance in the Planetary Nebula (PN) phase is characterised by the cessation of mass loss, a powerful and rapid stellar wind and a central star hot enough ($T_{eff} \geq 30{,}000$ K) to fully ionise the circumstellar environment. The luminous shell of ionised gas, expanding outward, will gradually diminish and disperse into the Interstellar Medium (ISM), contributing to the its enrichment (Kwitter & Henry, 2022). The central star will evolve towards a highly hot and

dense electron-degenerated object, a White Dwarf (WD), which will eventually cool down (Santamaría et al., 2020a). However, our understanding of the evolutionary processes both between and within each phase remains incomplete. In Section §2, I will outline the unanswered questions that require attention. In Section §3, I will detail new findings, and in Section §4, I will also explore other intriguing evolved objects. The conclusion will be provided in Section §5.

2. Open questions

Evolved intermediate-mass stars exhibit numerous processes and mechanisms that are highly likely to be interconnected, yet each one, both individually and collectively, remains elusive to our complete understanding.

Concerning PAGBs, eight key themes demand our attention: understanding the mechanisms that drive the intense mass loss observed during the AGB phase, affecting the PAGB; exploring the chemical composition and abundance patterns in the atmospheres of these stars (insights into nucleosynthesis and mixing processes); identifying the determining factors in the diverse evolutionary paths that PAGBs follow; investigating the evolution of circumstellar environments; exploring potential connections between PAGBs and the presence of exoplanets; assessing the impact of binary interactions on the evolution of these evolved stars; studying the formation of dust grains in the outflows of PAGBs; and finally, unravelling the nature of the ultimate fate of post-AGB stars, whether they evolve into planetary nebulae, white dwarfs, or other exotic objects.

Regarding PNe (Galactic and Extragalatic), there are similar challenges to address, and I have chosen to highlight eight of them. The first pertains to understanding the processes leading to the formation of PNe from precursor stars, with a focus on mass-loss processes. Next is determining the mechanisms involved in the transition from spherical to non-spherical nebulae. Another crucial aspect is accurately determining the chemical composition of PNe and their contribution to enriching the ISM. The evolution of central stars in terms of mass-loss rates, temperature evolution, and the formation of white dwarfs is also a key concern. A precise description of the dynamics of PNe and the application of 3D visualisation are vital for comprehensive understanding. Additionally, determining the origin of collimated outflows and jets, as well as the associated formation mechanisms, is essential. The role of binary systems in the formation and shaping of PNe needs exploration, and finally, understanding the relationship between planets and PNe is an intriguing area of inquiry.

Turning to WDs (which constitute a distinct realm in itself), various questions arise, encompassing aspects such as their detection methods, binary nature (including potential planetary companions) and merging capabilities, chemical and physical properties, and ultimately their evolution as Type Ia supernovae, along with the associated generation of gravitational waves.

3. New insights into the late stage of stellar evolution

3.1. Post-AGB stars

The primary information source for PAGBs is The Torún catalogue for Galactic post-AGB (Szczerba et al., 2007), which currently documents more than 300 PAGBs. The Spectral Energy Distribution (SED) of PAGBs enables the analysis of both the central star and the external shell. The latter can be classified into two categories: PAGBs with cold, detached, expanding dust shells, referred to as "Shell-type", and PAGBs with hot dust and circumstellar discs, known as "Disk type". New data from GAIA has also allowed for a more precise analysis of the luminosity. Disks play a crucial role in the investigation of PAGBs, serving as a vital component contributing to the non-spherical symmetry observed in these objects in contrast to their AGB precursor stars. Therefore, the“recipe” involves a rotating disk, a binary system within a common envelope, an accretion disk, and the launch of jets. This theoretical framework is substantiated by several observational findings. For instance, Bujarrabal et al. (2013) detected Keplerian rotating disks around 24 PAGBs using mm-wave observations of CO lines. Kluska et al. (2019) conducted VLTI/PIONIER interferometric observations in the H-band, capturing images of circumbinary disks. As mentioned earlier, jets and outflows are pivotal components. The latter were identified by Gallardo Cava et al. (2021) using the NOEMA interferometer, employing 12CO and 13CO J = 2-1 maps for PAGB 89 Her and 12CO J = 2-1 maps for AC Her, IRAS 19125+0343, and R Sct. In a separate study, Bollen et al. (2021) detected jets in five PAGBs through high-resolution spectroscopy. The inner jet velocities span from 155 to 443 km/s and it is interesting to notice that a mechanism inferred for the launch of those jets involves magnetism. Magnetic fields ($\vec{B}$) have indeed been identified in various PAGBs through diverse methodologies.Sabin et al. (2020) utilised dust polarisation to trace $\vec{B}$ in the envelope of OH 231.8+4.2, while Huang et al. (2020) and Vlemmings & Tafoya (2023) employed the polarisation of molecules in R CrT and OH 17.7-2.0, respectively. Sabin et al. (2015) detected and measured $\vec{B}$ at the photosphere of U Mon and R Sct, and Georgiev et al. (2023) demonstrated the variability of magnetic fields in R Sct. Perez-Sanchez et al. (2013) found synchrotron emission in IRAS 15445-5449 and concluded that a magnetic launching mechanism was responsible for the bipolar morphology. Finally, Leal-Ferreira et al. (2012) detected water masers in OH 231.8+4.2 and were able to measure $\vec{B}$. Additionally, it is important to note

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that several studies have been conducted to comprehend nucleosynthesis in PAGBs. For instance, the work by Kamath & Van Winckel (2022) highlights a chemical diversity within this population. Lastly, recent studies by Kluska et al. (2022) and Martin et al. (2023) propose the presence of planets in binary PAGB binary via their observations and analysis of the disks.

3.2. Planetary nebulae

The very recent IAU Symposium 384: "Planetary Nebulae: a Universal Toolbox in the Era of Precision Astrophysics" set the main characteristics of PNe as tracers of stellar evolution, hydrodynamics event, astrochemistry laboratories, abundance decoders and as unique tools to study the structure and evolution of galaxies[1]. The HASH (Hong Kong/AAO/Strasbourg H-alpha) planetary nebulae database Parker et al. (2016) currently reports 4,623 planetary nebulae, but it is estimated that more than 20,000 exist. To address this discrepancy, various surveys have been conducted, including MASH (Parker et al., 2006; Miszalski et al., 2008), IPHAS (Sabin et al., 2014; Ritter et al., 2023), and VPHAS+ (Sun et al., 2023). These surveys utilise diverse detection techniques such as visual observations, photometry, and machine learning. The newly discovered PNe exhibit characteristics such as faintness, large size, and evolved or compact structures. It is noteworthy to mention the substantial contribution from amateur astronomers in the search for these elusive planetary nebulae[2], leading to collaborative efforts (Le Dû et al., 2022). Addressing one of the main challenges in the field—the origin of the shaping of planetary nebulae—a consensus has emerged within the PN community. The prevailing view is that the non-spherical shape of PNe is primarily linked to the presence of a close binary system that has undergone common envelope evolution (Jones, 2020). However, it is essential to recognise that not all PNe are associated with a close binary system. In fact, the majority of intermediate-mass stars in binary systems do not undergo interaction throughout their evolution (Miller Bertolami, 2022). Furthermore, MHD models propose the critical requirement for a magnetic launching mechanism (García-Segura et al., 2022). Indeed, astrophysical jets play a crucial role, and both theoretical studies and observational research have revealed their significance. These findings have been facilitated by state-of-the-art observational techniques and instrumentation, as demonstrated in works such as Rechy-García et al. (2022). On a different theme, chemical abundances are a crucial aspect of PN research, but their determination is a challenging task. To tackle this issue, sophisticated photoionisation codes are employed. The Abundance Discrepancy Factor (ADF), potentially attributed to multiple plasma components or temperature fluctuations, remains a persistent issue (Méndez-Delgado et al., 2023), although high spectral resolution observations can significantly contribute to addressing this challenge (García-Rojas et al., 2022). The ongoing challenge of distinguishing between shock excitation and photoionisation also persists in the field. The studies mentioned here represent only a fraction of the extensive researches conducted by the PN community. Not covered here are investigations into distance determinations, the PN Luminosity Function, and the study of extragalactic PNe. Additionally, there are new evolutionary models for PAGBs and PNe proposed by Miller Bertolami (2016) which predict shorter PAGB timescales. I would refer the reader to the proceedings of the IAU 384 for more information.

3.3. White dwarfs

Weidmann et al. (2020) emphasised the extensive variety of central stars of planetary nebulae (CSPNe) and the diverse evolutionary paths they follow, a theme also explored in the work of Miller Bertolami (2022). The search for WDs is actively pursued, utilising data from GAIA EDR3 (Gentile Fusillo et al., 2021) and SDSS (Kilic et al., 2020), among other sources. Additionally, an intriguing aspect of these evolved stars lies in their connection to planets, as evidence of planetesimal objects or debris has been discovered around WDs (Vanderburg et al., 2020; Estrada-Dorado et al., 2023). In our discussion of binary systems, it's crucial to highlight the generation of Type Ia supernovae. WD J005311, known as Parker's star, and the nebula Pa 30 (discovered by an amateur astronomer!) are though to have originated from a dramatic merger involving two degenerate stars, either ONe/CO or CO/CO WDs, resulting in a Type Iax supernova. WD J005311 is so far the only known Type Iax supernova remnant in our Galaxy, providing a unique opportunity for in-depth study (Fesen et al., 2023; Schaefer, 2023; Lykou et al., 2023).

4. Peculiar and associated objects

In the realm of intermediate mass stars, there exist peculiar objects, including born-again planetary nebulae (Montoro-Molina et al., 2023), and various binary systems such as novae (Santamaría et al., 2020b), symbiotic systems (Huang et al., 2023), and cataclysmic variables (Guerrero et al., 2018). The comprehension of these objects, facilitated by high-resolution observational techniques and modelling, plays a crucial role in enhancing our understanding of (binary) evolved stars and the stellar feedback to the ISM.

5. Conclusion

I have outlined some of the open questions in the study of evolved intermediate mass stars and provided insights into how some have been addressed. Despite the substantial progress made in both theoretical models and observational techniques, there remain complex issues to explore. Fortunately, with the advent of new and upcoming

[1] I thank Joel Kastner for sharing his notes.
[2] Planetary Nebulae.net

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instrumentation like ALMA, LMT, EELT, ngVLA, and the application of innovative techniques such as machine learning, the future looks promising for advancing our understanding of these evolved stars.

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The Magellanic Clouds and their star clusters (Invited contribution)

B. Dias[1] and the VISCACHA team[1]

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Keywords: *galaxy: evolution, galaxies: star clusters: general, Magellanic clouds*

Abstract

The Large and Small Magellanic Clouds (LMC and SMC) are the two most massive satellite galaxies surrounding the Milky Way. They are likely in their first infall to our Galaxy and have just passed pericentre. Their orbit has been dragging a 200 degrees-long gas trailing stream and also a leading gas structure. The LMC-SMC pair has been interacting to each other with multiple encounters throughout their lives, which heavily impacted their structure, triggered star formation and boosted star cluster dissolution. The chemical evolution of these two galaxies is much less efficient than expected, and they are different in various regions of the SMC for example. Understanding this complex history requires a lot of precise chemical and kinematic information as a function of time and space combined to sophisticated chemo-dynamical models. The star clusters are excellent fossils because we can measure their 3D position, 3D velocities, age, metallicity, internal structure, and they trace the different regions of the LMC and SMC, as well as covering a large age range. In this talk, I briefly reviewed the topic and presented the VISCACHA survey that I lead involving astronomers from a handful of Latin America countries.

Resumen

La Grande y la Pequeña Nube de Magallanes (LMC y SMC, por sus siglas en inglés) son las dos galaxias satélites más masivas que rodean a la Vía Láctea. Es probable que estén experimentando su primera caída hacia nuestra galaxia y acaban de pasar el pericentro. Su órbita ha arrastrado un flujo de gas de 200 grados de longitud y también una estructura de gas líder. El par LMC-SMC ha interactuado entre sí con múltiples encuentros a lo largo de sus vidas, lo que ha afectado significativamente su estructura, ha desencadenado la formación de estrellas y ha impulsado la disolución de cúmulos estelares. La evolución química de estas dos galaxias es mucho menos eficiente de lo esperado y difieren en varias regiones, como en el caso de la SMC. Comprender esta historia compleja requiere una gran cantidad de información química y cinemática precisa en función del tiempo y el espacio, combinada con modelos químico-dinámicos sofisticados. Los cúmulos estelares son excelentes fósiles porque podemos medir su posición tridimensional, velocidades tridimensionales, edad, metalicidad, estructura interna y rastrean las diferentes regiones de la LMC y SMC, abarcando también un amplio rango de edades. En esta charla, revisé brevemente el tema, presenté el proyecto VISCACHA que lidero, en la que participan astrónomos de varios países de América Latina.

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1. Introduction

The Large and the Small Magellanic Clouds (LMC, SMC), or Tapi'i Hugua and Coxi Hugua in their tupi-guarani denominations[1], respectively, are two irregular galaxies that are Milky Way satellites. They have been studied systematically for decades and the most popular paradigm was that these two galaxies have been orbiting our Galaxy possibly since early times, and for the past 2 or 3 orbits they synchronized and became a pair orbiting the Milky Way with a period of about $\sim$ 2 Gyr (see e.g. Diaz & Bekki, 2012). A change of paradigm happened with the updated *HST*-based proper motions for the LMC and SMC (Kallivayalil et al., 2006b,a). They were adopted by

[1] http://www.astro.iag.usp.br/~viscacha/

the then PhD student Gurtina Besla in what is today her most cited paper (Besla et al., 2007). She proposed that the LMC and SMC have been a pair of galaxies that are most likely in their first infall into the Milky Way. A third big complement to the change of paradigm was the astrometric information from *Gaia* revealing that the LMC brought not only the SMC but a whole system of smaller dwarf galaxies forming a Magellanic System falling into the Milky Way (Sales et al., 2017; Kallivayalil et al., 2018). The LMC, SMC, and the other satellites of the Magellanic Clouds might have been interacting among them and leaving marks, the most famous being the Magellanic Bridge (e.g. Zivick et al., 2018). Among many purposes, the VISCACHA (VIsible Soar photometry of star Clusters in tApii and Coxi HuguA) survey team (Maia et al., 2019; Dias et al., 2020) has been using the star cluster systems of the LMC and SMC, observed in detail to help constraining the internal structure, kinematics, and chemistry of the Magellanic Clouds and searching for signatures of past interactions. The VISCACHA survey has been collecting images with the 4m SOAR telescope, improved by ground-layer adaptive optics system SAM imager (Tokovinin et al., 2016).

2. The effects of galaxies mergers

We highlight the results from two recent VISCACHA papers where the systematic observations of star clusters are used to trace back the chemo-dynamical evolution of the Magellanic Clouds and provide independent constraints for future models. The age-metallicity relation (AMR) of the SMC clusters (Fig.1) is known to display an intrinsic metallicity dispersion (e.g. Parisi et al., 2022). Dias et al. (2014) proposed a framework to help understand the complex chemical evolution history of the SMC by splitting the sky regions (see e.g. Dias et al., 2022).

Oliveira et al. (2023) studied star clusters along the Wing/Bridge, which is the main branch of the Magellanic Bridge. They found that the AMR does not show dispersion, but rather it reveals two metallicity dips related to the formation of the Magellanic Stream and Magellanic Bridge itself (see Fig. 1). Saroon et al. (2023) analyzed clusters in the opposite side, the West Halo region, and found that these clusters are systematically more metal-poor than those from the bridge, and they also show less dispersion in the AMR. Moreover, they revealed a clear metallicity dip and ran some chemical evolution models to conclude that it can only be explained by a major merger. Given the recent results showing that the LMC has multiple smaller satellites, it is not unlikely that a major merger could have been the origin of what we know today as the SMC.

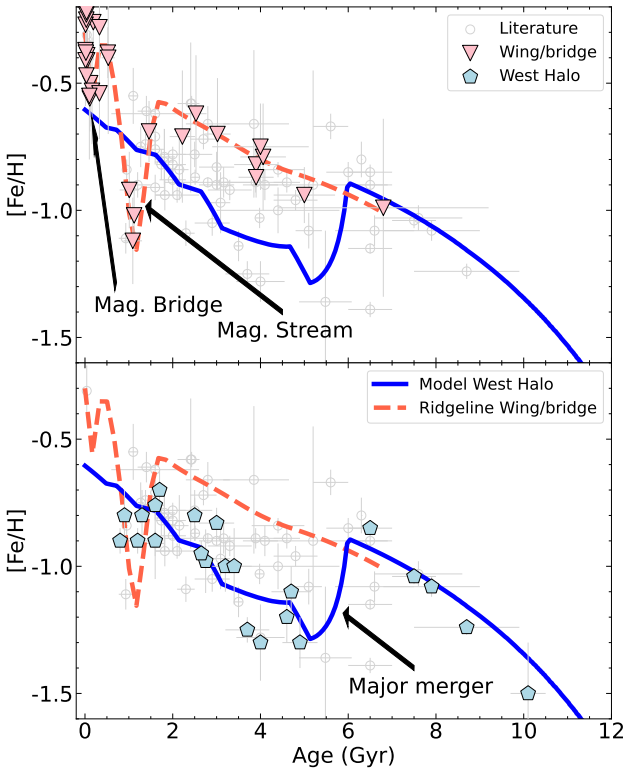

Figure 1. The age-metallicity relation for SMC clusters. Literature data shows a high metallicity dispersion. The SMC West Halo clusters can be described by a single chemical evolution model with a metallicity dip produced by a major merger around 6 Gyr ago. The SMC Wing/Bridge clusters are systematically more metal-rich than the West Halo group, and their evolution shows two metallicity dips at the formation time of the Magellanic Stream $\sim$ 1.5 Gyr ago and the Magellanic Bridge $\sim$ 200 Myr ago.

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The extremely sharp transition from H^+ to CO in the Horsehead nebula revealed by ALMA

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Keywords: *ISM: clouds, ISM: molecules*

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We present the most detailed image of the molecular gas in the photo-dissociation region (PDR) located at the edge of the Horsehead Nebula. The derived gas physical conditions and distances between the transition zones are consistent with stationary isobaric PDR models. However, dynamical effects can still be relevant in shaping the observed molecular cloud structure.

Massive stars can determine the evolution of molecular clouds by eroding and photo-evaporating their surfaces with strong UV radiation fields (e.g., Kim et al., 2018; Pabst et al., 2019). Thus, probing the fundamental structure of nearby molecular clouds is crucial to understand how massive stars shape their surrounding medium and how fast molecular clouds are destroyed. Although previous efforts have been made in well-known sources such as the Orion Bar PDR (Goicoechea et al., 2016), we must study the molecular gas exposed to more moderate UV radiation fields to obtain constraints representative of the molecular gas exposed to typical Milky Way illumination conditions.

Located at a distance of about 400 pc and viewed nearly edge-on, the illuminated edge of the Horsehead Nebula has been commonly considered a benchmark source for low-UV illuminated PDRs (Abergel et al., 2003). By combining CO $J = 3-2$ and HCO^+ $J = 4-3$ data from the ALMA 12m array, the Atacama Compact Array (ACA) and Total Power (single-dish), we present the highest angular resolution ($\sim$ 0.″5, corresponding to 207 au) and velocity-resolved images of the molecular gas emission in the Horsehead nebula (Hernández-Vera et al., 2023).

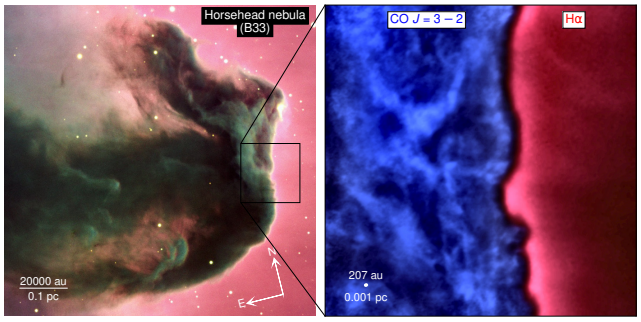

Figure 1. Multiphase view of the different gas phases at the edge of the Horsehead nebula, where the extremely sharp transition from ionized (traced by Hα in red) to molecular gas (traced by CO in blue) is clearly delimited. Figure extracted from Hernández-Vera et al. (2023).

We find that CO and HCO^+ are present at the edge of the cloud, very close to the ionization (H^+/H) and dissociation fronts (H/H_2), suggesting a very thin layer of neutral atomic gas and almost no CO-dark H_2 gas at the molecular cloud edge (see Fig. 1). Notably, the HCO^+ emission map exhibits a bimodal behavior, tracing the cold and dense gas shielded from UV radiation and a more diffuse gas component interacting directly with the UV

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radiation field. Additionally, using CO as a proxy of the C^+/C/CO front, we conclude that the distances between the fronts can be reproduced by isobaric stationary models, which confirms the presence of a steep density gradient, as suggested by previous observations (Habart et al., 2005). Still, dynamical effects cannot be completely ruled out, and even higher angular observations will be needed to unveil their role.

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Structure, kinematics and time evolution of the Galactic Warp revealed by Classical Cepheids

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Keywords: *Galaxy: disc, Galaxy: kinematics and dynamics, Galaxy: structure*

In this work we presented an analysis of the warp's structure using a Fourier decomposition in vertical high (Z) and vertical velocity (V_z) traced by Cepheids. Also, we found that the joint analysis of the Fourier decompositions in Z and V_z reveals the time evolution.

The warp is a well-known undulation of the Milky Way disc. Its structure has been widely studied, but only since Gaia DR2 has it been possible to reveal its kinematic signature beyond the solar neighborhood. In this work, we explore with detail the structure, kinematics, and time evolution of the warp considering its asymmetries without assumptions on the radial dependency of the Fourier parameters.

To study the warp, we have used the catalogue of Milky Way Cepheids from Skowron et al. (2019). The catalogue contains 2385 Classical Cepheids from which 1997 meet our quality filters. We cleaned the sample by keeping stars with RUWE < 1.4, an error in $Z \leq 0.1$ kpc, and an error in $V_z \leq 13$ km/s. To decompose the warp signal, we divide the disc into various concentric rings, and in each of them we fit a Fourier sum (up to the $m = 2$ mode) to Z and V_z.

We found a clear but complex signal that reveals an asymmetrical warp in both variables. In Z we found the warp to be almost symmetric in amplitude at the disc's outskirts but with the two extremes never diametrically opposed at any radius. The line of nodes presents a twist in the direction of stellar rotation for $R > 11$ kpc (black line in Fig. 1).

For the kinematics, we found that in V_z an $m = 2$ mode is needed to represent the kinematic signal of the warp, reflecting its azimuthal asymmetry. We also found that the line of maximum vertical velocity (green line in Fig. 1) is similarly twisted but does not overlap with the line of nodes, it trails behind by ≈ 25 deg, we conclude that this

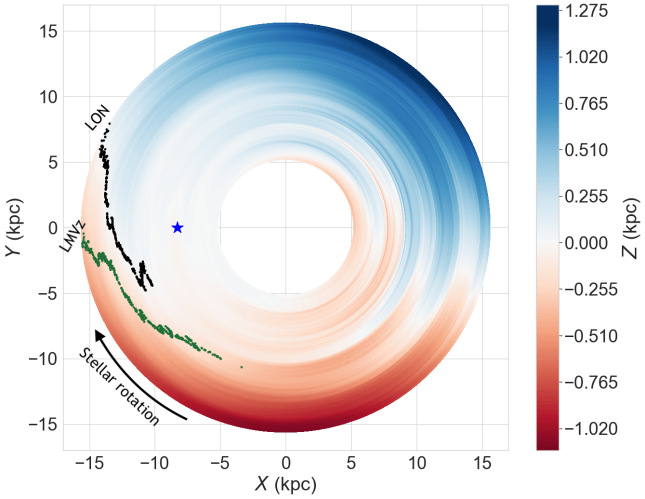

Figure 1. Face-on view of the best fitting warp model for the Cepheids. The color scale represents the mean Z of the disc (blue above the plane and red below it). The line of nodes (LON) (black curve). The dark green curve indicates the line of maximum vertical velocity.

is due to the lopsidedness of the warp. We have shown how the twisted line of maximum V_z creates "arches" in the mean V_z as a function of radii, a signature of global warp kinematics that has been observed with other tracers with less azimuthal coverage of the disc (Cheng et al., 2020; Gaia Collaboration et al., 2021).

Finally, a joint analysis of the Fourier decompositions in Z and V_z allows us to develop a new model-independent formalism to derive the pattern speed and change in amplitude of each mode at each radii. By applying it to our results for the Cepheids we found, for the $m = 1$ mode, a constant pattern speed in the direction of stellar rotation of 9.18 ± 3.1 km/s/kpc, a constant amplitude up to

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$R \approx 14$ kpc and a slight increase in amplitude at larger radii, in agreement with previous works (Dehnen et al., 2023).

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Unveiling the 3D geometry of nova shells with MUSE

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Keywords: *cataclysmic variables, ISM: kinematics and dynamics, novae, techniques: imaging spectroscopy*

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Nova shells are the remnants of the nova eruptions in cataclysmic variables. Understanding the physical process that shapes the geometry of these shells is necessary to fully comprehend the physical processes behind a nova eruption. Recent efforts have been made to study several nova shells using integral field spectroscopy (IFS), which allows for a complete spatio-kinematic description of the shell material. In this proceeding, we present the preliminary results of our survey of nova shells observed with IFS with an emphasis on the 3D reconstruction of the shells.

The study of nova shells using integral field spectroscopy is a recent development despite the obvious advantages it possesses. We started a project to observe several shells using the Multi-Unit Spectroscopic Explorer located at Paranal Observatory, Chile. The wavelength coverage of the instrument (470-900 nm) allows us to study the main lines observed in these shells, like Hα and [OIII]. The targets were selected based on the previous observations of Gill & O'Brien (1998), and Downes & Duerbeck (2000), in order to study the evolution of these shells during the last 20 years.

From the sample of shells, the most suitable for analysis is RR Pic, due to the combination of its age and proximity. The analysis of this shell reveals that its geometry is composed of an equatorial ring and polar filaments, which have been preserved during the last 20 years while expanding without showing signals of deceleration. The 3D reconstruction of the shell reveals that the equatorial ring possesses a radius ∼8000 au and it is surrounded by several "clouds" of material (see Celedón et al. (2024) for details on the 3D reconstruction). The overall geometry of the shell is consistent with the prolate shape expected for nova shells (Aydi et al., 2020).

More intriguing is the nova shell around the system V1425 Aql, which is composed of an inner shell traced mainly by Hα+[NII] and an asymmetric outer shell traced by [OIII] (Tappert et al., 2023). Following the methodology developed for the analysis of RR Pic, we determine the 3D geometry of the inner and outer shell of V1425 Aql, which is presented in Fig. 1, revealing that the geometry of the outer shell corresponds to an arc-like structure surrounding the inner shell.

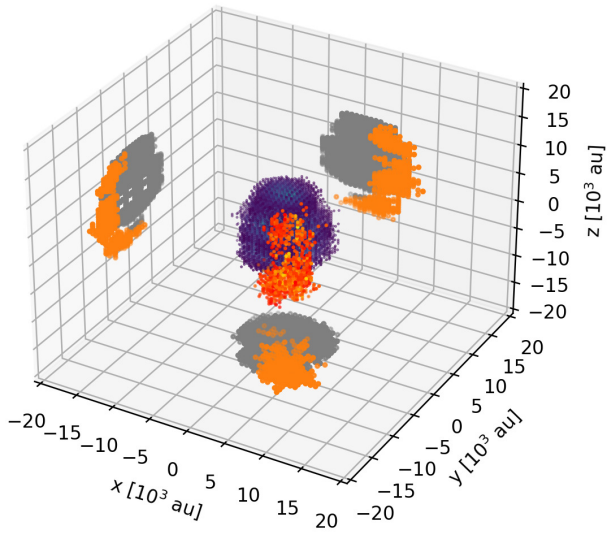

Figure 1. 3D reconstruction of the nova shell around V1425 Aql. The inner shell traced by Hα+[NII] is presented in blue colours with its projections in grey, while the outer shell traced by [OIII] is presented in red colours and its projections in orange.

Due to the strong blending between the Hα and [NII] emissions we were not able to separate the contributions of these lines individually, and so the reconstruction overestimated the actual length of the shell in the z-axis, explaining why the outer shell appears to be shifted with respect to the inner one in this axis.

The study of nova shells with MUSE opens new perspectives to understand the physical phenomena that shape these structures.

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Keeping track of nearly a hundred stellar streams in the Milky Way: the galstreams library

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Keywords: *Galaxy: kinematics and dynamics, Galaxy: stellar content, Galaxy: Structure*

In this contribution I showcase the latest version of the galstreams library, a compilation that collates information scattered across the literature for over a hundred stellar streams known in the Milky Way.

Stellar streams play in dynamics a similar role as stellar clusters do in stellar evolution: they are relatively simple systems of stars whose common properties allow rewinding evolutionary or dynamical processes that would be much harder to disentangle in the Galactic field. Formed as stars are stripped from a dwarf galaxy or globular cluster by the Milky Way's tidal forces, stellar streams are fossil records of accretion that are best preserved in the halo, where streams are long lived. Unearthing this record is essential to reconstructing the Galaxy's accretion history, and modeling its dynamics is key to constrain the distribution of dark matter at the scales of the Galaxy and its satellites.

The *galstreams* library (Mateu, 2023) is an effort to keep track and collate the information available for the stellar streams reported in the literature in a homogenized format. Figure 1 shows the timeline of discoveries of stellar streams, illustrating the exponential growth experienced by the field in the last few years, driven by the advent of exceptionally deep and wide photometric surveys (e.g. PS1, DES Flewelling et al., 2020; Abbott et al., 2018) and the landmark of the Gaia second and third data releases (Gaia Collaboration et al., 2018, 2023), in which proper motion information became available for the first time for millions of stars spanning the entire sky to great depths. These landmarks have ushered in a new era where studies of stellar streams can expand from modeling individual systems to ensemble modeling, with the consequent improvements this implies for the inference of dynamical parameters both for the stream's progenitors as for the Milky Way itself.

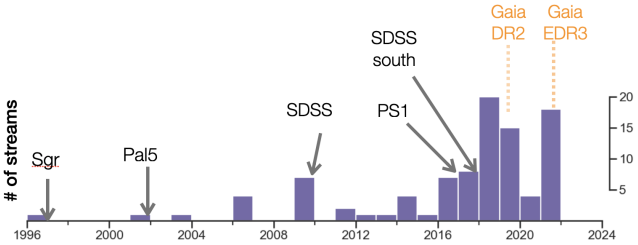

Figure 1. Timeline of stellar stream discoveries, based on the discovery year for the streams reported in the *galstreams* library.

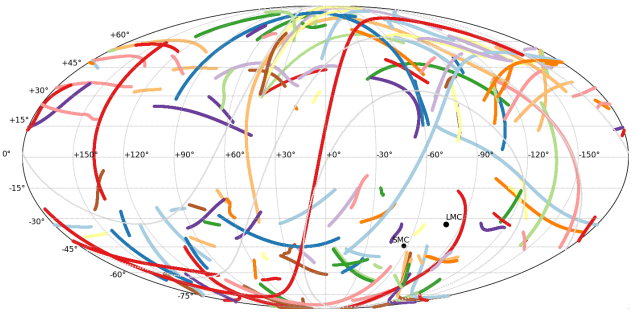

Figure 2. Celestial distribution, in Galactic coordinates, of the > 100 stellar stream tracks catalogued in the *galstreams* library v1.0.1.

The library is publicly available at the *galstreams* GitHub repository[1] and described in detail in Mateu (2023). Figure 2 showcases the celestial tracks reported for over a hundrer unique stellar streams available in *galstreams*. In addition to the celestial coordinates, information about distance along the track, and when available, proper motions and radial velocities are provided for each stellar stream track. The library is implemented in Python and based on `astropy` SkyCoord functionality.

[1] https://github.com/cmateu/galstreams

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Radio spectra of the classical nova V5668 Sgr

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Keywords: *stars: binarie, stars: novae: V5668Sgr, stars: radio continuum*

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The classical nova V5668 Sgr erupted on 2015, March 15. It was observed with ALMA on 2017 (Diaz et al., 2018) 927 days after eruption, showing for the first time, that the nova shell is formed by clumps of sizes $\sim 10^{15}$ cm (Fig.1a). V5668 Sgr was observed with the VLA, although not resolved, at frequencies ranging from 1.3 to 35 GHz (Chomiuk et al., 2021), between days 2 and 1774 after eruption (Fig.1b). In this work we show that it is possible to reproduce all the VLA spectra, assuming that the clumps were formed early in the nova evolution.

A nova eruption is the result of a thermonuclear explosion at the surface of a white dwarf (WD) in a close binary system. The companion star transfers matter to the WD, an accretion disk is formed around the WD and when enough matter is transferred, thermonuclear reactions occur at the base of the disk. The disk is ejected at velocities of $\sim$ 1000 km s^{-1}. The ejecta expands and forms a shell, while nuclear reactions continue at the surface of the WD. The fastest wind from the WD interacts with the slower ejecta, producing radiative shocks, clumps, and γ-ray emission. As the shell expands, soft and hard X-ray emission is detected.

In our model, the shell is formed by a number $N_{\rm cl}$ of identical spherical, homogeneous clumps, although the model is also valid if the clumps have a power law distribution of sizes (Abraham et al., 2024). The clumps emit free-free radiation and the observed spectrum is the sum of the individual spectra of the clumps. The parameters of the model are electron temperature $T_{\rm e}$, number density $n_{\rm H}$, and radius $R_{\rm cl}$. We verified that models with constant temperature (1.21×10^4 K, as obtained from models of optical and infrared line emission) fit the VLA spectra after day $t = 635$ after eruption; before, the temperatures necessary to fit the data were higher. After day 635, the density of the clumps decreased as $n_{\rm H} \propto t^{-3}$. Based on this result we propose that the clumps are in pressure equilibrium with a hotter and thinner plasma which fills and expands with the shell, which at earlier epochs was

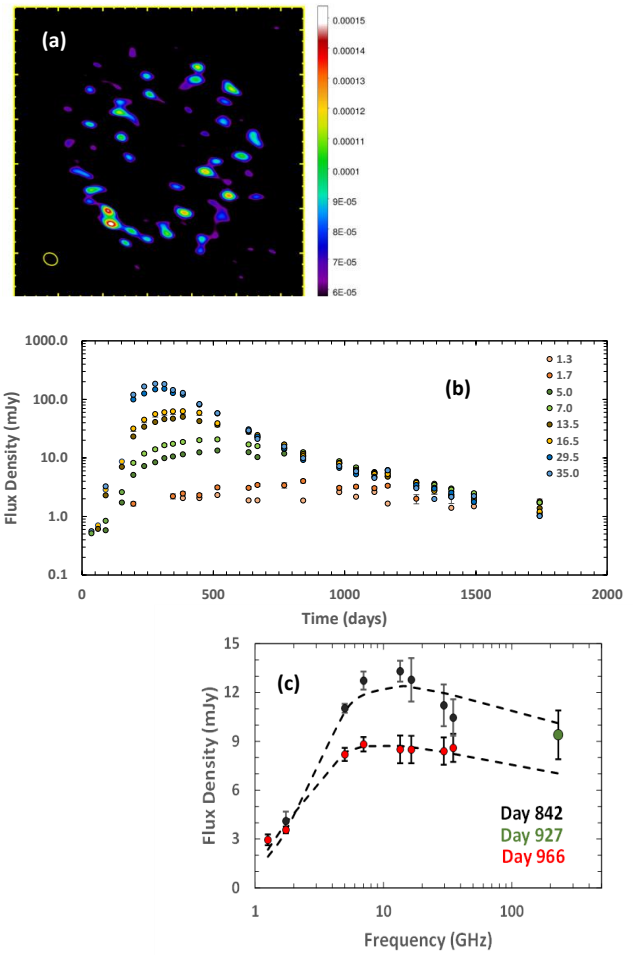

Figure 1. (a) 230 GHz continuum image of V5668 Sgr, (b) VLA light curves, (c) VLA spectra at two epochs (points), with adjusted model (lines) and 230 GHz ALMA data.

responsible for the observed X-ray emission. In fact, the X-ray emission calculated from this model coincided with the observed hard X-ray flux. The total mass of the clumps

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was 1.9×10^{-5} $M_\odot$, for $N_{cl} = 40$ while the mass of the hot material was 3.5×10^{-7} $M_\odot$.

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Systematic census of RR Lyrae in cluster vs. tails of stellar streams with an associated cluster

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Keywords: *(Galaxy:) globular clusters: general, stars: variables: RR Lyrae*

We present first results of a systematic census of RR Lyrae in stellar streams with an associated cluster. Out of 16 stellar streams studied, we found 6 with more than 2 RR Lyrae in the tails. Of those, none present an RR-Lyrae type segregation as the one previously observed in Pal 5's stellar stream. However, the M92 stream may present a metallicity segregation where the RR Ly.

Galaxies like ours have formed gradually, progressively assimilating smaller galaxies. These accretion events have left fossil records, an important part of these are the globular clusters and stellar streams present in the Galactic halo. Studies have revealed that a large number of globular clusters fell into the Milky Way along with their respective host galaxies. But, these are only the "surviving" clusters. During the accretion process, clusters and dwarf galaxies can be disrupted in the halo thanks to tidal forces, generating stellar streams.

Our general aim is to search for RR-Lyrae (RRL) associated with all known stellar streams. The RRL are horizontal branch pulsating stars known for being standard candles, in this way, we can obtain precise distances of the stars being able to determine the distance gradient of the stellar stream. This will be needed to determine its dynamic properties.

In a first exploration for the Pal5 stellar stream 10 RRL were found in the cluster and 17 in the tails (Price-Whelan et al., 2019); in the M68-Fjorm stream the opposite is found, while there are over 40 RRL in the cluster, only less than a handful are found in the tails. Furthermore, in the case of Pal5 the RRL are segregated: The majority of the RRc (8/12) are in the cluster while the majority of the RRab (13/15) are in the tails (Price-Whelan et al., 2019).

We studied 16 stellar streams with an associated cluster using the union of GaiaDR3, PS1, ASAS-SN-II, ZTF, and OGLE RRL catalogs; and the sky, distance and proper motion tracks from galstreams library (Mateu, 2023) taken as "truth". Members are found using a probabilistic model in distance and proper motion following Price-Whelan et al. (2019) and Foreman-Mackey et al. (2014).

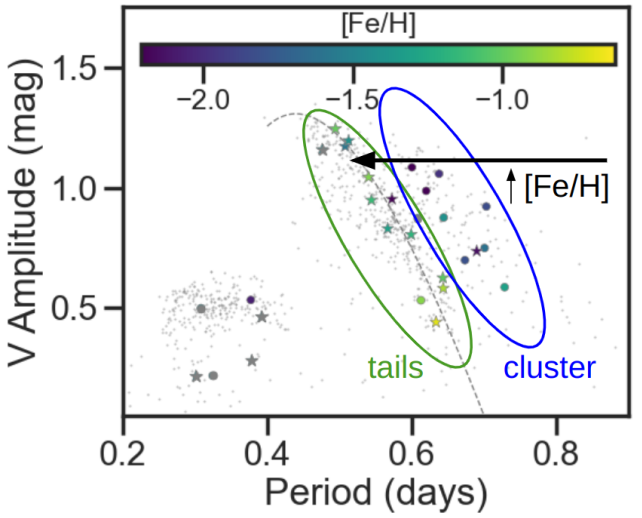

Figure 1. Period-amplitude diagram of the RRL from M92 stellar stream. Star symbols are the RRL of the tails and circle symbols are the RRL of the cluster. The color indicates the spectroscopic metallicity of the star measured by Gaia.

After systematic census, only 6/16 of the stellar streams present several (> 2) RRL in the tails/total: NGC 2808 (22/29), M92 (16/29), Pal5 (15/24), NGC 1851 (6/17), NGC 3201 (5/90), Tucana III (5/5). These are the ones truly worthy to do the complete inference without assuming the distance and proper motion tracks.

None of them present a RRL type segregation as Pal5, but M92 present a metallicity segregation: tails metallicity (~ -1.5) > cluster metallicity (~ -2.2) (see Fig. 1). This means a mixed population is less metal-rich in the inner part, and it could imply that M92 is a globular cluster and the tails are its disrupted host dwarf galaxy.

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Hidden jets in planetary nebulae and how to find them

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Keywords: *ISM: jets and outflows, ISM: kinematics and dynamics, (ISM:) planetary nebulae: general*

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Almost 80% of the planetary nebulae (PNe) are non-spherical - elliptical, bipolar, point-symmetric, among others - sometimes showing knots, filaments and jets of low ionization (the low-ionization structures, LIS), and others features of small scales. The presence of stellar jets in PNe has been investigated through morpho-kinematic studies, from narrow-band images and position-velocity maps constructed from high-dispersion, long-slit spectroscopic observations. However, this spectroscopic technique limits the understanding of the global three-dimensional structure of the PNe, since the spatial and spectral information are only obtained along a given orientation. Integral field units (IFU) allow the spatial and kinematics mapping of PNe, for both their small- and large-scale components, to determine their morphology, kinematics, density distribution, and the interaction zone of the jets with the surroundings. Many of the stellar jets have only been unveiled through this modern instrumental technique. In this talk, I will present results obtained with the optical IFU MEGARA, which highlight the hidden ways that PNe ejecta return their products to the interstellar medium, in a variety of morphologies. In particular: i) the extension of the extremely faint bipolar jet in NGC 2392, mapped for the first time; ii) the kinematic dissection of the born-again HuBi 1; iii) the multiple structures of the M2–31, and finally iv) the presence of a fast outflow aligned with the symmetry axis of M3-38.

The study aimed to detect hidden jets in four planetary nebulae (PNe) using the IFU MEGARA (High Resolution GTC Multi-Spectrograph for Astronomy, (Gil de Paz et al., 2018)) attached on the Gran Telescopio Canarias (GTC). We used the high-resolution Volume-Phased Holographic (VPH) grism VPH665-HR covering the 6405.6-6797.1 Å wavelength range. The four PNe studied and the results found are the following:

HuBi 1: A PN with a [WC 10] central star, exhibiting an uncommon ionization structure, with the outer shell showing higher ionization compared to the innermost regions (Guerrero et al., 2018). Velocity tomography revealed shell-like structures expanding at $\simeq$ 300 km s^{-1} (Rechy-García et al., 2020).

NGC 2392: This PN has a complex morphology and presents high-velocity bipolar outflows. MEGARA provided the first image of its jets, showing velocities with the approaching component jet is between -190 km s^{-1} to -150 km s^{-1}, and receding from +150 km s^{-1} to +190 km s^{-1} (Guerrero et al., 2021).

M 2-31: A compact PN with a [WC4-6] central star. Five kinematic components were identified with MEGARA (Rechy-García et al., 2021).

M 3-38: This PN has a binary system and a fast collimated outflow with a velocity of 225 km/s. MEGARA observations detected additional high-velocity clumps orthogonal to its bipolar axis (Rechy-García et al., 2022)

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An integrated Hα flux atlas of planetary nebulae in the Magellanic Clouds: Combining S-PLUS photometry and spectroscopic analysis

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This study presents an atlas of Hα + N II fluxes for Magellanic Cloud Planetary Nebulae (MC PNe) using S-PLUS imaging and spectroscopic data from the literature. Our methodology generated Hα + N II flux maps for numerous MC PNe, emphasizing method reliability through spectroscopic-photometric comparisons. Visual representations showcased S-PLUS data fidelity in capturing spectral features. Ongoing work addresses refinements in analysis techniques and broader applications of these flux maps for distance and temperature calculations.

Southern Photometric Local Universe Survey (S-PLUS; Mendes de Oliveira et al. (2019)) utilizes a 0.8m telescope, offering comprehensive 12-band imaging using J-PLUS crafted filters (Cenarro et al., 2019). Our study aims to generate an integrated Hα + N II flux atlas for MC PNe, crucial for understanding their emission characteristics and physical properties.

Data sources include S-PLUS imaging, spectroscopy, and literature references for Magellanic Cloud PNe. We employed a methodology involving *r*, *J*0660 and *i* filters to derive integrated Hα + N II fluxes. Creation of Hα + N II maps utilized Python code developed by Lopes et al. (in prep.), and validation involved pseudo-slit creation and comparative spectroscopic measurements.

Figure 1 displays the combined RGB image and Hα + N II flux map for PN LHA 115-N 1, utilizing S-PLUS data to explore ionized gas in planetary nebulae. The figure also compares the VLT/X-shooter spectrum (Euclid Collaboration et al., 2023) with S-PLUS photometry for the same PN, emphasizing the observed consistency between spectroscopic data and photometric observations. This highlights the S-PLUS data's efficacy in capturing essential spectral features crucial for PN characterization. The comparative analysis of spectroscopic and photometric Hα + N II fluxes for seven PNe (*right bottom*) emphasizes method reliability, prompting an investigation into critical discrepancies for refining measurements. Ongoing work addresses N II effects, integrates additional spectra, and refines analysis techniques; future objectives include the broader utilization of Hα flux maps for distance and temperature calculations.

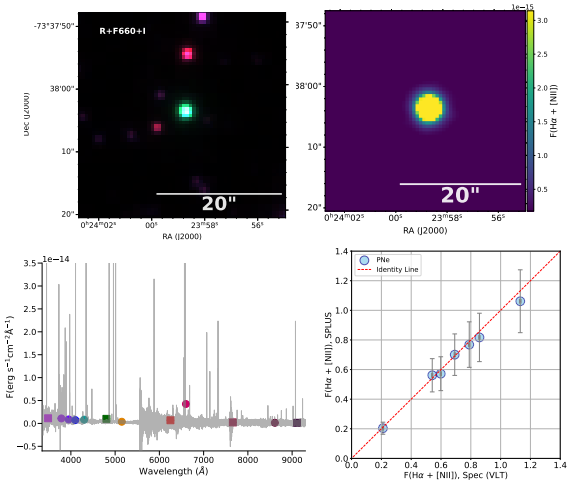

Figure 1. *Upper panel:* Displays an RGB image composed from *r*, *J*0660, and *i* filters (*left*) alongside the corresponding Hα + N II flux map (*right*). *Bottom panel:* Illustrates S-PLUS photometry overlaid with VLT/X-shooter spectra of PN LHA 115-N 1 (*left*). Additionally, it presents a comparison between integrated Hα + N II fluxes obtained from spectroscopy and photometry for seven PNe of the SMC, highlighting both their consistencies and discrepancies (*right*).

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BETIS: Bidimensional Exploration of the warm-Temperature Ionized gas

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Understanding the relationship between stellar formation processes and the interstellar medium (ISM) is a key step in discerning the complexity of the evolutionary history of galaxies. A problem in this regard has been understanding the nature and importance of feedback processes in which massive stars deposit energy into the interstellar medium through photoionization, stellar winds, and supernovas. This feedback mechanism affects the physical and dynamic state of the ISM and, therefore, influences the rate and distribution of stellar formation in galaxies. In this context, the existence of a warm and ionized component of the ISM that is distributed ubiquitously in galaxy disks has been known for decades, both in our Galaxy and in extragalactic sources. This component is called Diffuse Ionized Gas (DIG).

In this work, we define a sample of 265 galaxies observed with the MUSE IFS instrument on the VLT-8.1m telescope to conduct a spectral study and spatial analysis of the DIG. We explore the distributions of low-ionization species [OIII], [OI], [NII], and [SII] in DIG regimes along the galactic planes and discern the different ionization mechanisms resulting in this gas. We create a methodology based on the generation of emission line maps from MUSE data cubes after synthesizing stellar populations for each spaxel. Additionally, we develop an adaptive binning method to increase the signal-to-noise ratio of weaker lines, such as [OIII], [OI], and [SII]. We test this methodology using a subset of the BETIS sample consisting of 7 different galaxies.

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Is the oldest planetary nebula really a member of the open cluster M37?

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We have found very strong evidence that an extended bipolar planetary nebula (PN), lying in the line-of-sight of the Galactic open cluster M37, is actually its physical member- only the third such instance confirmed in the Galaxy. The rarity of such an association underlies the importance of its detailed study. This analysis, combined with our previous data of open cluster PNe, provides valuable independent data to the fundamental initial-to-final-mass relation that is vital for stellar evolution studies and for understanding the enrichment of both carbon and nitrogen in the Galaxy. We estimated the properties of the PN and its progenitor from Gaia DR3 cluster color-magnitude diagrams and Padova theoretical isochrone fitting. Among our remarkable results, we emphasize the following: we found the mass of the progenitor star to be around 2.8 $M_{\odot}$. The nebula is huge (having a major axis of 445 arcsec), which implies a kinematical age of around $80x10^3$ yrs- the oldest PN ever recorded- suggesting that PNe in clusters do not dissipate as fast as those in the field.

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Investigating the potential of methanol as a shock tracer in the AGN-starburst galaxy NGC 1068 with UCLCHEM

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The behavior of methanol (CH_3OH) in the composite galaxy NGC 1068 was analyzed to investigate its effectiveness as an extragalactic shock tracer and to study the effect of shock velocity (v_s) and formation routes (gas and solid state mechanisms) on the predicted interstellar abundance of methanol. With a parameterized C-shock physical model, C-shock chemistry was investigated with `UCLCHEM` to study the chemical abundance of CH_3OH as a function of time in different locations of the Circumnuclear Disc (CND) near the active galactic nuclei (AGN) and the starburst (SB) ring of NGC 1068. It is concluded that the gas-phase methanol can trace C-type shocks as its abundance increases significantly due to grain sputtering or sublimation during shock propagation. This increase in the abundance is consistent for both low ($\sim$ 10 km/s) and high ($\sim$ 45 km/s) velocity shocks. It is also shown that the main reaction leading to the formation of methanol in the grain is the radical-molecule H-atom abstraction route, which is in good agreement with Simons et al. (2020) and Santos et al. (2022). These modeling results will be contrasted with observed methanol abundance from Atacama Large Millimeter/submillimeter Array (ALMA) from Huang et al. (2023, submitted) and discussed with different parameters explored, such as gas temperature (T_k), density (n_{H_2}), and cosmic-ray ionization rate (ζ) and their dependence on methanol formation under the studied conditions.

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Chemical properties of the SMC Main Body traced by star clusters

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We derived radial velocities and Ca II Triplet (CaT) metallicity of more than 150 red giant stars in six SMC star clusters and their surrounding fields, with the instrument GMOS on GEMINI South. The mean cluster radial velocity and metallicity were obtained with mean errors of 2.2 km/s and 0.03 dex, respectively. We add this information to that available for another 51 clusters and 30 fields with CaT metallicities on the same scale. Using this expanded sample we analyze the chemical properties of the SMC Main Body. We found a high probability that the metallicity distribution of the Main Body clusters is bimodal with a metal-rich and a metal-poor cluster group. Metal-rich clusters present a clear age-metallicity relation, while metal-poor clusters present no chemical enrichment throughout the life of the galaxy. We present observational evidence that the chemical enrichment is complex in the SMC Main Body.

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Astrochemical analysis of the nuclear environments of galaxies in the local universe

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Building upon previous research on the emission of polycyclic aromatic hydrocarbons (PAHs) in the mid-infrared (mid-IR), the present work studies a sample of 28 local galaxies (D $\leq$ 30Mpc) from the Spitzer Survey of Near-infrared Galaxies (SINGS). All objects show optical signatures of an active galaxy nucleus (AGN), and PAHs are also detected. The sample covers 28 nuclear regions, one for each galaxy. Molecules in each region were identified by fitting them with the NASA Ames PAH IR Spectroscopic Database (PAHdb). The molecules present were categorized into families based on their composition: PAH, amorphous (molecules that contain only carbon in their formula), nitrogen-bearing polycyclic aromatic hydrocarbons (N-PAHs), and Polycyclic Aromatic Hydrocarbons with heteroatom (any atom other than hydrogen, carbon, or nitrogen). With this categorization, it is easy to notice, in general, that PAHs and amorphous ones, such as C24, have the highest flux contribution in the studied regions. The C24 molecule has a remarkable contribution to the flux of some galaxies. When categorizing the molecules it is possible to notice that the percentage of PAH is predominant in most of the galaxies, while the amorphous ones predominate in the others. The percentages of N-PAH and heteroatom change little or nothing between the galaxies. The next goal is to determine what conditions are causing the different flux contributions of each family of molecules depending on the environment. In addition, laboratory studies using the C24 molecule and PAHs with 24 carbon atoms will be carried out using the techniques of time-of-flight mass spectrometry (TOF-MS) and infrared spectroscopy (FTIR), to verify the stability and the pathways of break-down of these species under radiation field.

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Kinematics, Metallicities, and Ages of the Inner 2 Degrees of the Bulge of the Milky Way

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Ages and kinematics play a crucial role in Milky Way's Bulge studies, as they contain valuable information about its formation history. Photometric studies have concluded that most bulge stars are around 10 Gyrs old. On the other hand, high-resolution spectroscopy of microlensed bulge stars suggests that 2/3 of super-solar metallicity stars are younger than ∼6 Gyrs. We will use deep observations from HST and VLT/MUSE, in the low extinction SWEEPS window, to measure, for the first time, spectroscopic metallicities for turnoff stars. This will allow us to obtain a clean turnoff for each of the two main metallicity components (sub-solar and super-solar) and derive their relative age. Note that we will decontaminate from disk foreground stars as the proper motions from HST are available. Shallower VLT/MUSE data in the inner bulge (b<2°) will be used to derive the radial velocity distribution, and then the 3D velocities, by cross-match with the proper motion from VVV available to our group. This will allow us to fully characterize the velocity dispersion peak reported by a few authors in the bulge innermost region. The analysis of the 3D velocity will allow us to establish whether the detected radial velocity peak is due to anisotropies, or to a genuine larger velocity dispersion, thus related to a larger concentration of mass. Our results will provide crucial data to constrain dynamical models of the Milky Way central region.

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VISCACHA Survey: the SMC Southern Bridge in 8D

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The Magellanic Bridge is a stream of gas and stars connecting the Magellanic Clouds, formed by tidal forces as a consequence of a close encounter between the SMC and LMC ∼ 200 Myr ago. We performed a 6D phase−space vector, plus age and metallicity, analysis of star clusters in the Southern Bridge. We derived distances, ages, metallicities and velocities from the VISCACHA Survey photometric data and its Gemini/GMOS spectroscopic follow-up, also adopting proper motions from the GAIA Survey. We found that Southern Bridge clusters are moving towards the LMC and share the kinematics of the Northern Bridge. Also, we reinforced the idea that the two Bridge branches have not experienced the same chemical evolution.

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Revealing dense gas kinematics in the G012.80 protocluster

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We study the dense N_2H^+ (1-0) gas in the nearby (2.4 kpc) and massive ($4.6 \times 10^3\ M_\odot$) protocluster G012.80 observed as part of the ALMA-IMF large program. We combined our analysis with additional ALMA-IMF tracers such as H41α, SiO, $C^{18}O$ and dense core catalogs. We modeled the full N_2H^+ emission and constructed intensity-weighted position-velocity (PV) diagrams in the full region. Here, we find that ∼30% of the spectra have 2 velocity components (peaks separated by 2.1 km s^{-1}), and the remainder are well-fit by a single component. In PV diagrams, we observe zig-zag and twisting velocity structures pervasively in the dense gas traced by our N_2H^+ observations. We do not detect N_2H^+ emission in the center of G012, where the H41α and continuum emission are concentrated, likely due to radiative feedback effects arising from massive star formation. We calculated velocity gradients in two subregions in G012 (R1 & R2) that present different features in PV diagrams. R1 is associated with a potential filament rotation signature and is dominated by the first velocity component. In contrast, R2 is associated with core accretion features in PV diagrams and is dominated for both velocity components (first and second). We obtained corresponding timescales for R1 & R2 of 0.07 Myr (equivalent velocity gradient 15.3 km s^{-1} pc^{-1}) and 0.11 Myr (8.8 km s^{-1} pc^{-1}) respectively. The next steps involve analysis of column density by optical depth estimations and mass profiles in both sub-regions, especially in R2 where the current $N(H_2)$ data is well detected.

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IGRINS Chemical Tagging of Stars in Streams to Progenitors: Fimbulthul

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We propose near-infrared (near-IR) high-resolution spectroscopic follow-up of selected stellar streams to perform a detailed elemental abundance analysis. The stream candidates were identified over the whole sky, and a few selected stars have previously been observed during observations from IGRINS/Gemini. Using near-IR spectra we aim to perform the first Chemical Tagging of potential stream stars, linking them to their progenitor streams. The new spectral data will allow us to confirm or discard the possible association of these streams with known globular clusters, and provide additional information for a set of chemical species (C, N, O, Mg, Al, Si, Ti, Ni, Cu, Co, Ce, Nd, Yb, among others) accessible from the H-band. We will also examine the presence or absence of the multiple-population phenomenon in the selected streams, and its relation with globular clusters, and strongly constrain the dynamical history for both stars observed with IGRINS and their progenitors.

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Galaxy evolution across the Cosmic Web: A review (Invited contribution)

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Keywords: *cosmology: large-scale structure of Universe, galaxies, galaxies: clusters, galaxies: evolution*

Abstract

From a galaxy's point of view, its environment has continued to evolve during its lifetime, going from lower to higher density regions as it moves across the cosmic web. This paper reviews our current understanding of the effect of environment on galaxy evolution, including the consequences of gravitational interactions between galaxies, and hydrodynamical interactions between galaxies and their host group or cluster. Some recent studies on galaxies caught in the act of transformation are highlighted, including the spectacular "jellyfish" galaxies which are in the process of gas stripping due to intense ram-pressure by the intracluster medium. We further discuss the current challenges in our understanding of galaxy evolution, including the complexity imposed by the hierarchical formation of structure which leads galaxies to be "pre-processed" in groups and filaments prior entering a massive cluster. Finally, we provide an overview of the ongoing and future observational efforts in the South America.

Resumen

Desde el punto de vista de una galaxia, su entorno evoluciona durante su vida, pasando de regiones de densidad baja a regiones de densidad alta a medida que atraviesa la red cósmica. Este artículo revisa nuestra comprensión actual del efecto del entorno en la evolución de las galaxias, incluidas las consecuencias de las interacciones gravitacionales entre galaxias y las interacciones hidrodinámicas entre galaxias y el grupo o cúmulo en el que habitan. Se destacan algunos estudios recientes sobre galaxias en pleno acto de transformación, incluidas las espectaculares galaxias "medusa" que están en proceso de barrido de gas debido a la intensa presión del medio intra cúmulo. Además, se discuten los desafíos actuales en nuestra comprensión de la evolución de las galaxias, incluida la complejidad impuesta por la formación jerárquica de estructuras que lleva a las galaxias a ser "pre-procesadas" en grupos y filamentos antes de ingresar a un cúmulo masivo. Finalmente, se destacan algunas campañas observacionales actuales en América del Sur.

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1. Introduction

In a hierarchical Universe clusters grow via the accretion of galaxies from the field, filaments, groups and even other clusters. As galaxies migrate from low to high density environments within the cosmic web, they can lose their gas reservoirs via different mechanisms, eventually quenching their star-formation and transforming morphologically. Evidence for this includes the increased fraction of early-type galaxies in dense environments at the expense of late-types (known as the morphology-density relation; Dressler, 1980); a bimodality of the colour-density relation (Hogg et al., 2003, 2004); the consistent decrease in the fraction of star forming galaxies in cluster cores (Lewis et al., 2002; Gómez et al., 2003; Bamford et al., 2009; von der Linden et al., 2010); as well as increasing gas deficiencies (e.g. Solanes et al., 2001; Jaffé et al., 2015).

It has now been established that galaxies are quenched by a combination of internal (e.g. AGN) and external processes (Peng et al., 2010).

This review focuses on external mechanisms which can be divided into two main types (see Boselli & Gavazzi, 2006; Boselli et al., 2022, for a review): **(i)** Gravitational or tidal mechanisms such as galaxy-galaxy interactions and mergers, interactions between galaxies and the

gravitational potential of the host cluster, and the so-called "harassment", or cumulative high-speed encounters between galaxies. These kinds of interactions are expected to affect both the stellar and gaseous mass within galaxies. **(ii)** Hydrodynamical interactions between cluster galaxies' gaseous component and the hot intra-cluster medium (ICM) can result in gas stripping due to ram pressure thermal evaporation or turbulent/viscous stripping. All of these processes alter the gas content/consumption cycle of galaxies, altering their ability to form new stars and also their morphologies, and are thus fundamental to understand galaxy evolution. For example, galaxy mergers between two gas-rich star-forming spirals can result into a quiescent elliptical, and gas stripping of cluster spirals could potentially lead to form S0 galaxies (which where rarer in the higher redshift Universe; Desai et al., 2007).

In this (biased) review, I highlight a few recent efforts in understanding *how, when, and where* galaxies exhaust or loose their gas reservoirs, quench their star formation, and transform morphologically as a function of their environment.

2. Galaxy evolution in clusters

Galaxy clusters are one of the largest and densest concentrations of matter in the Universe and are known to accelerate galaxy evolution.

In particular, large spectroscopic surveys covering galaxy clusters have established that the quenching of the star formation occurs as galaxies "virialize" into the host cluster (see e.g. Haines et al., 2013; Pasquali et al., 2019).

There is mounting evidence that ram-pressure stripping (RPS) is among the most effective mechanisms removing gas from galaxies and subsequently quenching them in cluster environments (Cortese et al., 2021). The most striking observations of RPS at play come from measurements of the abundance and distribution of Neutral Hydrogen (HI) in infalling cluster galaxies (see Cortese et al., 2021, and references therein) which have revealed how cold gas is removed from the galaxies without altering the underlying stellar populations. Furthermore, Optical and Ultra-Violet (UV) observations have revealed the presence of young stars in the stripped tails of some cluster galaxies (e.g. Kenney & Koopmann, 1999; Cortese et al., 2007; Owers et al., 2007; Yoshida et al., 2008; Kenney et al., 2014; Gullieuszik et al., 2023). The most striking examples have been referred to as "Jellyfish" galaxies (Fig. 1).

Examples of "Jellyfish" galaxies started to appear increasingly more frequently in cluster studies in the past couple of decades in a variety of wavelengths, and more recently, large samples of jellyfish have become available (Poggianti et al., 2016; McPartland et al., 2016; Roberts et al., 2021), allowing for statistical studies of these galaxies undergoing intense transformations. With these samples and the use of phase-space diagrams to infer the orbital histories of galaxies it has been established that RSP is very effective on first infall into the cluster and is favoured in

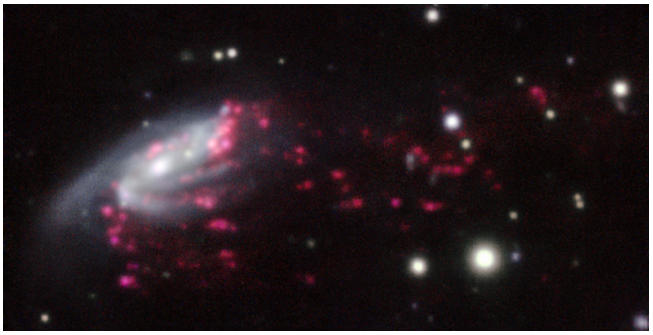

Figure 1. Example "jellyfish" galaxy (JO206) from the GASP survey (Poggianti et al., 2017a). The stars in the disk (white) are largely unperturbed, while the gas (H_α emission in pink) is clearly disturbed. The direction of the tails is assumed to be opposite to the direction of movement within the cluster. Image credits: GASP-ESO.

radial orbits (Jaffé et al., 2015, 2018; Roberts et al., 2021). The tail directions of the jellyfish galaxies can be used to further constrain the duration of the visible RPS features (Smith et al., 2022), which seem to appear close to the virial radius during first infall and disappear 650 Myr after pericentric passage (Salinas et al. *submitted*).

The details of how the stripping happens and its consequences on galaxy evolution are revealed by dedicated surveys such as VESTIGE (Virgo Environmental Survey Tracing Ionised Gas Emission; PI. A. Boselli) and GASP (the Gas Stripping Phenomena Survey; PI. B. Poggianti). In particular, GASP obtained MUSE/VLT (and follow-up multi-wavelength) observations for over 100 jellyfish galaxies revealing how gas is stripped from the outside-in in the galaxy disks as they fall deeper into the potential well of clusters. This process can lead to enhanced star formation in the disk, extra-planar star formation, and even unwinding of the spiral arm structure or activation of the central black hole (Poggianti et al., 2017a,b; Bellhouse et al., 2021).

3. Pre-processing in groups and filaments

Where do cluster galaxies come from?

The mass assembly of galaxy clusters, aside from the initial filamentary collapse, is primarily driven by accretion of smaller scale haloes such as the collapse of galaxy groups into a galaxy cluster. Cosmological simulations predict that massive ($\sim 10^{15} M_\odot$) clusters at $z = 0$ have accreted $\sim 40\%$ of their galaxies from groups (McGee et al., 2009).

The accretion histories of clusters, together with observational evidence for quenching of galaxies in group-sized haloes have led to the concept of pre-processing (Zabludoff et al., 1996). Recent observations have confirmed that significant pre-processing must be at play, since even at large cluster-centric radii well beyond the maximal rebound radius of backsplash galaxies ($2\lambda 3 \times R_{200}$), the star-forming galaxy fraction falls well short of that seen in the coeval field (Haines et al., 2015; Lopes et al., 2024).

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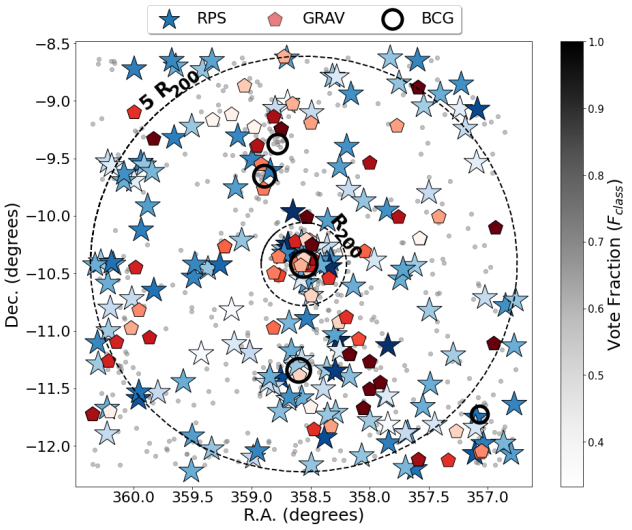

Figure 2. Distribution of interacting galaxies around the galaxy cluster A2670, split by type of interaction: Gravitational (red pentagons) and Hydrodynamical (RPS, blue stars). Both types are found in the cluster core and extend even out to $5 \times R_{200}$. The darkness of symbols correspond to the degree of confidence of the visual classification of the interacting galaxies. Grey dots correspond to other galaxies in the cluster and the open black circles mark the location of the 5 brightest ones. Adapted from Piraino-Cerda et al. 2023.

What remains unclear is what physical mechanisms drive galaxy evolution in those environments and how efficient they are in quenching and transforming galaxies.

In addition to groups, cosmic filaments are also key in understanding pre-processing as they contain 50% of the mass in the Universe even though they only make up 6% of the volume (Cautun et al., 2014). It has been found that, similarly to cluster environment, filaments can induce galaxy transformations, such as increased fractions of elliptical or red galaxies, quenching of star-formation processes, and increased stellar masses. However, the strength of these density relations are not as prominent as those found in within the galaxy cluster regions themselves and the transformation mechanisms in these environments remain vastly unknown.

4. Future Perspectives

To study pre-processing at play and understand the physical mechanisms transforming galaxies outside of clusters it is thus important to study galaxy clusters well beyond the virial radius and to study those galaxies that lie within large-scale filaments. This is only possible with large cosmological simulations and wide and deep photometric and spectroscopic surveys.

In the latin-american region, there are several large efforts including the The Souther Photometric Local Universe Survey (S-PLUS; PI. Mendes de Oliveira) is an ongoing multi-band optical survey designed to cover an area of 8,000 deg^2 down to i=21. S-PLUS is observing large areas around massive clusters at different redshifts in an efficient way, providing the means to obtain accurate photometric redshift, colour and stellar mass estimates for galaxies well beyond the virial radius.

Going to unprecedented depths, the upcoming LSST at the Vera Rubin Observatory will revolutionize our view of galaxy evolution by revealing the very low-surface brightness regime. With such sensitive data we will be able to characterize galaxy morphologies in a whole new way. The current trend is to utilize AI or parametric tools to classify and identify different kinds of galaxies and features (Bom et al., 2024). In addition to these efforts, there are a number of citizen science projects aiming at obtaining large samples of specific galaxy populations such as "jellyfish" galaxies[1].

On the spectroscopic side, the 4MOST facility will soon start operating in Chile, and will immensely increase the spectroscopic coverage of the southern sky. In particular, the 4MOST CHileAN Cluster galaxy Evolution Survey (CHANCES, PIs Haines & Jaffé) will study the evolution of over 300.000 galaxies in and around 100 clusters and superclusters over the last 4 Gyr of cosmic time (Haines et al., 2023), providing legacy support for the eROSITA X-ray mission. One of its unique aspects that it will push well beyond the virial radius of massive nearby clusters to cover the surrounding infall regions as far out as 5 times the virial radius from the cluster, permitting the effects of pre-processing on galaxies within infalling X-ray groups and filaments to be quantified in unprecedented detail down to the dwarph galaxy regime (r= 20.5).

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The co-evolution between galaxies and dark matter halos (Invited contribution)

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Keywords: *galaxies: evolution, galaxies: haloes, methods: statistical*

Abstract

In this proceeding we present the star formation history, SFH, of galaxies over cosmic time, ranging from dwarfs to massive ellipticals, using the semi-empirical modeling based on the new model EMPIRE. Progenitors of massive galaxies reveal distinct growth stages, with evidence suggesting that cold streams played a key role in sustaining star formation, SF, at higher redshifts, while virial shock heating became more prominent at lower redshifts.

Resumen

En estas memorias presentamos la historia de formación estelar SFH, de galaxias en una escala de tiempo cósmico, desde galaxias enanas hasta elípticas masivas, usando modelado semi-empírico basado en el nuevo modelo EMPIRE. Los progenitores de galaxias masivas revelan diferentes etapas de desarrollo, con la evidencia sugiriendo que las corrientes frías juegan un rol clave en el sustento de la formación estelar (SF) a alto corrimiento al rojo, mientras el calentamiento virial por choques se vuelve más prominente a corrimientos al rojo bajos.

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1. Introduction

The current cosmological model suggests that dark matter halos serve as the gravitational framework for galaxy formation, shaped by hierarchical structure formation and local astrophysical processes. This interdependence implies that the growth and assembly of halos may influence galaxy properties. Through the semi-empirical modeling, we can use observational data on galaxy demographics, including the galaxy stellar mass function and star formation rates (SFRs), along with dark matter assembly histories from $N-$body simulations (Rodríguez-Puebla et al., 2017). This approach enables us to explore the intricate relationship between halos and galaxies, specifically unraveling the SFH of galaxies over time. By adopting this framework, we gain a direct and interpretable cosmological understanding of galaxy formation and evolution, providing insights into the main mechanisms driving galaxy formation.

In this proceeding, we present the empirical SFH of galaxies as a function of their dark matter halos, utilizing the new semi-empirical model EMPIRE (Rodríguez-Puebla et al. in prep.)

2. The co-evolution between galaxies and dark matter halos

Figure 1 presents SFHs ranging from dwarf galaxies, with stellar masses M_*=10^8M$_\odot$, to giant ellipticals at the centers of large clusters, M_*~7×10^{11}M$_\odot$. The thick white lines depict the average growth history of central galaxies in dark matter halos with peak[1] masses at z=0 of $M_{\rm peak}$ = $10^{10.5}, 10^{11}, 10^{12}, 10^{13}$ and $M_{\rm peak}$=10^{14}M$_\odot$ utilizing merger trees from the SmallMultidark-Planck (SMDP) simulation (see Klypin et al. (2016) for details).

Galaxies, ranging from dwarfs to intermediate masses, $M_* = 10^8 - 10^{10}$M$_\odot$, have been forming stars at a roughly constant rate, approximately 0.1 M$_\odot$/yr for the smallest dwarfs, $M_* < 10^9 M_\odot$, $\sim$ 0.5 M$_\odot$/yr for small galaxies $M_* \sim 5\times10^9 M_\odot$ and $\sim$ 5 M$_\odot$/yr for the intermediate ones $M_* \sim 10^{10} M_\odot$. Milky Way (MW)-sized galaxies exhibit a

[1]refers to the largest mass ever achieved by a dark matter halo during its history.

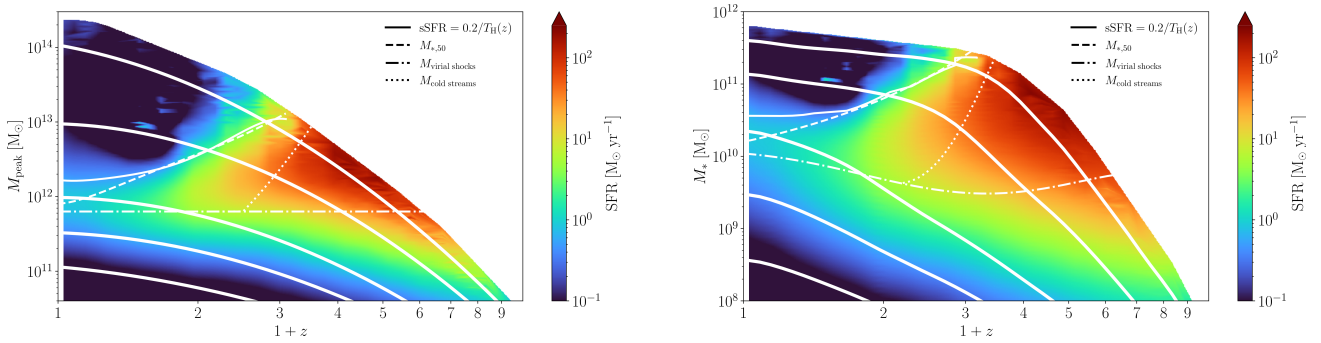

Figure 1. Star formation histories as a function of $M_{\rm peak}$ (left panel) and M_* (right panel) for progenitors at $z = 0$ with masses $M_{\rm peak} = 10^{11}, 10^{11.5}, 10^{12}, 10^{13}$ and 10^{14}M$_\odot$. The solid line indicates the threshold when the sSFR= $0.2/T_{\rm H(z)}$ where $T_{\rm H}$ is the Hubble time at z, the dashed line indicates when 50% of galaxies are actively forming stars, and the dot-dashed and dotted lines represent the mass limits for coldstreams and shock-heated gas, respectively. The star formation histories of central galaxies in the most massive halos reached their peak below the cold stream mass limit, eventually undergoing quenching.

more complex SFH compared to dwarfs and intermediates. The SFH of MW-sized galaxies increased by a factor of ~ 20 between $z \sim 3.5$ and ~ 1 reaching a maximum of around 10 M$_\odot$/yr before declining. In contrast, more massive galaxies, on average, have undergone elevated periods of star formation. The progenitors of giant ellipticals reached an average of ~ 200 M$_\odot$/yr between $z \sim 3-4$, followed by a rapid decline.

The formation process of massive galaxies with $M_* > 10^{11}$ M$_\odot$ ($M_{\rm peak} \sim 10^{13}$ M$_\odot$) is complex and involves distinct stages. Initially, when their halos had masses below $M_{\rm peak} \sim 6 \times 10^{11}$ M$_\odot$ (approximately $M_* \sim 0.2 - 0.4 \times 10^9$ M$_\odot$ for all z) gas accretion was highly efficient due to the short cooling time compared to the dark matter's dynamical time. During this phase, gas freely fell into the galaxy, leading to an elevated period of star formation and causing galaxies to grow by approximately two orders of magnitude from $z \sim 6-8$ to $\sim 3-5$.

As halos reached masses around $M_{\rm peak} \sim 6{\times}10^{11}$ M$_\odot$ the incorporated gas was heated by virial shocks, resulting in longer cooling times. The gas temperature rose to levels where baryonic cooling efficiency decreased, limiting cold gas from forming stars. If the cooling time was shorter than the halo's dynamical time, the gas fell (within a cooling radius) and settled in the galaxy (White & Frenk, 1991). Alternatively, if the cooling time was longer, the gas was unable to radiate thermal energy, forming a (quasi-) hydrostatically balanced atmosphere (halo quenching, Dekel & Birnboim (2006)). Surprisingly, the empirical evidence that is deduced from Fig. 1 shows that galaxies continued to exhibit elevated periods of star formation even as most of the progenitors of today's massive galaxies crossed the halo mass quenching transition (dot-dashed line).

It is worth noting that at intermediate redshifts, $z \sim 2-4$, hot halos could be penetrated by cold streams (Kereš et al., 2005), supplying sufficient gas to sustain star formation in massive halos between $z \sim 2-5$. This gas supply facilitated not only mass growth but also an increase in central density, contributing to the growth of supermassive black holes (SMBHs), coinciding with the peak epoch of high SMBH accretion (Kormendy & Ho 2013). As cold streams became less efficient and halo quenching took over (the region above the dotted line in Figure 1), the star formation history (SFH) experienced a strong suppression by $\sim 2-3$ orders of magnitude, below $z \sim 1-2$. Specifically, the sSFR dropped below $0.2/T_{\rm H(z)}$ where $T_{\rm H}$ is the Hubble time at z, leading these galaxies to become part of the population of quiescent galaxies (solid and dashed lines). Despite the suppression of SF, galaxies were still able to grow by a factor of $\sim 2-3$ through galaxy mergers since $z \sim 2$.

3. Conclusion

In this work, we explored the complex interplay between galaxies and their halos, shedding light on the SFH of galaxies over cosmic time using the semi-empirical model EMPIRE. The presented SFHs in Figure 1 unveil the varied evolutionary trajectories of galaxies, spanning from dwarfs to massive ellipticals. Particularly noteworthy are the discernible growth stages observed in the progenitors of massive galaxies. The data aligns with the notion that, at higher redshifts, cold streams played a key role in sustaining star formation in massive galaxies, while virial shock heating might become more prominent at lower redshifts.

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Mapping the universe with galaxies: astronomy, cosmology, and artificial intelligence (Invited contribution)

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Keywords: *cosmology: observations, cosmology: large-scale structure of Universe, galaxies: evolution, galaxies: formation, methods: data analysis, techniques: spectroscopic*

Abstract

This text discusses the cosmic web as a tool to enhance our understanding of galaxy evolution and refine our knowledge of cosmological parameters. It explores recent advances at the intersection of astronomy, cosmology, and artificial intelligence, aiming to extract valuable insights from the cosmic web. As an illustrative example, I showcase the Dark Energy Spectroscopic Instrument (DESI), a Stage-IV spectroscopic survey constructing the most comprehensive 3D map of the universe. Emphasis is placed on how machine learning techniques have been crucial to DESI's scientific mission.

Resumen

Este texto analiza la red cósmica como una herramienta para mejorar nuestra comprensión de la evolución de las galaxias y perfeccionar nuestro conocimiento de los parámetros cosmológicos. Explora los avances recientes en la intersección de la astronomía, la cosmología y la inteligencia artificial, con el objetivo de extraer conocimientos valiosos de la red cósmica. Como ejemplo ilustrativo, menciono el Instrumento Espectroscópico de Energía Oscura (DESI), un estudio espectroscópico de Etapa IV que construye el mapa 3D más completo del universo. Se hace hincapié en cómo las técnicas de aprendizaje automático han sido cruciales para la misión científica de DESI.

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1. Astronomical Achievements

By November 2023, the Dark Energy Spectroscopic Instrument (DESI) collaboration had gathered approximately 27 million galaxy spectra since it started taking science data in May 2021 (DESI Collaboration et al., 2024). This singular number serves as an indicator of the exponential growth in the capabilities for gathering extragalactic spectra since the early eighties of the past century (Schlegel et al., 2022).

DESI was meticulously designed with the ambitious goal of creating the largest and most detailed three-dimensional map of the Universe to date (DESI Collaboration et al., 2022). Its primary objective is to characterize the filamentary structure of matter distribution on the largest scales, known as the cosmic web, with unprecedented detail (DESI Collaboration et al., 2016).

The 3D map created with DESI will serve as the foundation for constraining cosmological parameters, including the time evolution of the dark energy component, aimed at elucidating the accelerated expansion of our Universe. The primary mathematical tool for this purpose is the isotropic two-point correlation function, pioneered by Jim Peebles and refined by observers, theorists, and simulators studying the universe's large-scale structure (Peebles, 2001).

However, a distinctive feature of the cosmic web is its anisotropy, leading to the emergence of new methodologies to quantify anisotropic effects within the cosmic web, enabling new constraints on cosmological parameters (Li et al., 2014).

Furthermore, as cosmic web studies have matured, the traditional cosmic web elements (peaks, sheets, filaments,

and voids) have evolved into valuable tools for constraining cosmological parameters. Recent advancements suggest that all cosmic web types are valuable for these constraints (Paillas et al., 2024)

2. Cosmology with the Cosmic Web

At a conceptual level, the current spatial distribution of galaxies relies on two factors: the initial conditions in the universe and the physical laws governing its evolution. Cosmic web science aims to use observed patterns for inferences about these initial conditions and evolutionary laws. For instance, pioneering work in the early eighties demonstrated that the observed galaxy distribution pattern required cold dark matter in the universe's initial conditions (Davis et al., 1985).

In the first decade of the 21st century, cosmic web studies primarily focused on simulations, leading to diverse algorithms classifying the cosmic web into four types: peaks, filaments, sheets, and voids. In the second decade, some algorithms were applied to observational datasets, mainly focusing on identifying voids or filaments. For a comprehensive overview of cosmic web finders, refer to the paper "Tracing the Cosmic Web" (Libeskind et al., 2018).

The cosmic web has found application in various scientific cases, including:

- Determining the position of the Local Group in the cosmic web and assessing the extent of its configuration's commonality in the standard cosmological model (Forero-Romero & González, 2015).
- Quantifying the alignment of dark matter halo shapes, their angular momentum, and peculiar velocities with the cosmic web (Forero-Romero et al., 2014).
- Constraining cosmological parameters by leveraging the anisotropy of the filamentary structure of the cosmic web (Li et al., 2014).

3. Artificial Intelligence in Cosmic Web Science

Due to the significant increase in data volumes compared to previous surveys, Artificial Intelligence (AI) plays a crucial role within DESI across survey design, operations, and data interpretation.

For instance, in the design phase, Machine Learning (ML) and Deep Learning (DL) techniques assist in target selection, defining low-contamination galaxy samples (Darragh-Ford et al., 2023).

In survey operations, ML has been used to identify outliers in spectroscopic data, often stemming from instrument glitches. Addressing these issues involves hardware/software corrections, challenging through visual inspection alone given the vast data quantities (Suárez-Pérez & Forero-Romero, 2022).

On the interpretation front, novel analysis techniques utilize DL algorithms trained on simulated universes to predict cosmological parameters from data similar to DESI's observed 3D map (Villanueva-Domingo & Villaescusa-Navarro, 2022). Convolutional Neural Networks could also be used to estimate cosmological parameters provided that a dark matter reconstruction could be built with DESI data (Pan et al., 2020).

4. Summary

In summary, here are my three key takeaways:

- DESI is a novel experiment, mapping the galaxies in the Universe with unprecedented detail.
- The cosmic web provides sufficient anisotropic information to help constrain cosmological parameters.
- AI plays a crucial role within DESI, impacting survey preparation, operation, data processing, and interpretation.

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Evolution of the orbital structure in self-consistent N-body simulations

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Keywords: *galaxies: bulges, galaxies: structure, galaxies: evolution, methods: numerical*

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We present a comprehensive analysis of the orbital dynamics in three N-body models, each consisting of a stellar disk embedded within a dark matter halo. As these models undergo evolution, bars naturally form within the galactic plane, exhibiting different buckling stages depending on the initial conditions. Subsequently, the bars take on varied shapes such as boxy, peanut, or elongated forms. We assess the orbital evolution by conducting frequency analyses on phase space coordinates for all disk particles at 1 Gyr intervals. Despite the short integration time and notable early-time bar evolution, histograms of the ω_z/ω_x ratio (the vertical frequency to the frequency along the bar major axis) for particles from the 2:1 family exhibit a consistent pattern, transitioning from a high to low ω_z/ω_x ratio as the bar evolves. After the initial Gyr, the disk-dominated model develops a boxy structure lasting for 1 Gyr before transitioning to a peanut shape, which persists until the end of the simulation. The intermediate model manifests a boxy structure after 2 Gyr, enduring for approximately 2 Gyr before evolving into a peanut shape. In contrast, the halo-dominated model develops the boxy structure much later, around 3 Gyr, and the peanut morphology is only incipient at the end of the simulation (7 Gyr).

We studied the orbital structure evolution for three N-body models from Valencia-Enríquez et al. (2019, 2023) using the dominant frequencies of the disk particles. The models differ on the values of the initial Spin parameter of the disc λ_d. We recalculated the simulations with high time resolution to get the frequencies of the orbits in the disk particles.

In order to analyze these frequencies, we take the bar frame of reference where the bar is in a horizontal position for all snapshots. We calculate the frequencies of the orbits from each disk particle using the phase space coordinates as a function of discrete time ($x(t)$, $y(t)$, $z(t)$, $v_x(t)$, $v_y(t)$, and $v_z(t)$ for Cartesian coordinates, and the azimuthal position $\theta(t)$ and the radial velocity $v_r(t)$, for cylindrical coordinates) in each Giga year of evolution. Therefore, we analyze the orbital frequency distribution of the bar structure in a disk galaxy as the bar potential evolves.

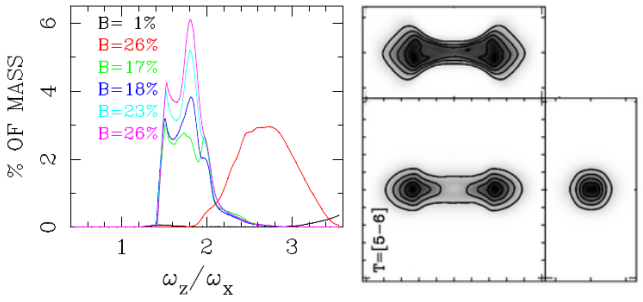

Figure 1. The left side shows histograms of orbital frequency for ω_z/ω_x ratio and the contribution to the bar orbits. The colors represent the time interval of one Giga-year of frequency analysis: black, red, green, blue, cyan, and purple lines are for 0-1, 1-2, 2-3, 3-4, 4-5, and 5-6 Giga-years, respectively. The right side of the figure represents the orbits assembly density profile (OADP) in edge-on (top panel), face-on (bottom left panel), and end-on (bottom right panel) views for Barred orbits from the disk dominate model for the last time interval.

We focused on bar-type orbits, which fill the $1.9 < \omega_R/\omega_x < 2.1$ interval, where we found that before the bar formation, the ratio ω_z/ω_x shows high values, see red line of Figure 1, during the bar formation, a phenomenon called "buckling" takes place and pushes orbits out of the galactic plane. In this process, the vertical frequencies move to lower values; see the rest of the lines, which represent the evolution of the frequency analysis. On the other hand, the "buckling" is responsible for the formation of the peanut and/or the X shape observed in edge-on-barred galaxies. This process is shown in the right side of Figure 1.

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Strategies for the creation of the VVV near-IR Galaxy catalogue in a northern part of the galactic disc

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Keywords: *galaxies: statistics, infrared: galaxies*

We presented the methodology for the automatic classification of galaxies and non-galaxies in low Galactic latitude regions using both images and photometric/morphological near-IR data from the VVVX survey. Using the VVV NIRGC (Baravalle et al., 2021), we analyzed the most relevant features for galaxy identification through classical and un-supervised statistical methods. This catalogue was also used to generate datasets of extragalactic candidates from a pipeline (Baravalle et al., 2018) and to train a Convolutional Neural Network (CNN) with image data and an Extreme Gradient Boosting (XGBoost) architecture with photometric and morpho- logical data. This allows us to derive probability catalogues used to analyze completeness and purity as a function of configuration parameters and to explore the best combinations of the models. The resulting classifier achieves an F1-score of 0.67, a purity of 65 percent, and a completeness of 69 percent. As a test case, we applied this methodology to the VVVX survey in part of the Northern disc region, generating a dataset of 172,396 extragalactic candidates with probabilities of being galaxies. We studied the impact of implementing supervised models trained with data from different regions of the Galactic disc. The methodology chosen to create a catalogue of galaxies automatically is subject to a decision threshold of 0.6 and the combination of using imaging and photometric/morphological information. We compared the precision metrics of galaxies obtained in the VVV disc and Northern disc. We took two sets of 1,682 candidates to be galaxies that had probabilities greater than or equal to 0.6 for either model (CNN and XGBoost). The probability distribution of galaxies for each model in the VVV disc and Northern disc regions are shown in Figure 1. We found that the models tend to reproduce the identification characteristics in regions with visual inspection. These results confirm the estimated purity in the galaxy catalogues generated from the methodology detailed in Daza-Perilla et al. (2023). Currently, we are

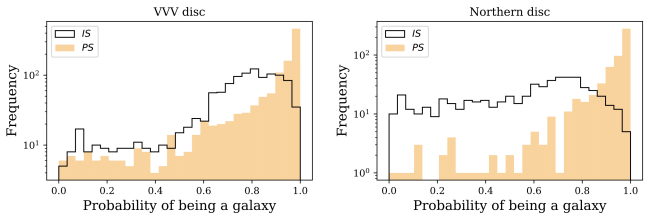

Figure 1. Probability distribution of galaxies. The probabilities of being a galaxy for the CNN model trained with IS are shown in black, and in orange the distribution of probabilities of being a galaxy for the XGBoost model trained with PS. The y-axis is shown in logarithmic scale. Upper panel: Galaxies belonging to VVV. Lower panel: Galaxies belonging to the Northern disc (Figure 13 in Daza-Perilla et al. (2023)).

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performing transfer learning to improve identification in low Galactic latitude regions and to generate a new catalogue of galaxies across the entire Galactic disc.

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SMARTY: The mileS Moderate Resolution neAr infRared sTellar librarY

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Keywords: *galaxies, galaxies: stellar content, infrared: galaxies*

We present a 0.35-2.4 μm stellar spectral library composed by 31 stars observed with the Gemini Near-IR Spectrograph (GNIRS) on the 8.1 m Gemini North telescope in Mauna Kea, Hawaii. These stars are present in the MILES library, and thus various parameters derived from the optical are available. Furthermore, out of those, 26 are presented for the first time in the NIR and 5 were used as control sample. The SMARTY library will be made available to the community.

Most of the observed galaxies cannot be resolved and therefore are studied through the evolutionary synthesis of simple stellar populations (SSPs). Spectroscopic observations are increasingly being directed towards the near-infrared (NIR, e.g. James Webb Telescope), thus we need to understand the stellar populations that dominate the galaxies' light in this spectral region. However, due to observational and theoretical difficulties, different SSP models differ in their predictions in the NIR.

In this context, having reliable stellar libraries in the NIR is essential as this is one of the most important ingredients to develop reliable stellar population synthesis models. The stellar libraries can be either theoretical or empirical, each offering distinct advantages and limitations. However, both theoretical and empirical libraries not only benefit from but also depend on each other. For example, empirical stars derive their atmospheric parameters through comparisons with theoretical stars, while theoretical stars can undergo testing and calibration based on empirical stars.

In light of these considerations, the SMARTY library comprises 31 stars carefully selected from the MILES stars (Sánchez-Blázquez et al., 2006), strategically positioned across diverse regions of the HR diagram. This selection was intended to facilitate the test of theoretical stars. In Fig. 1, the comprehensive coverage of empirical NIR stellar libraries is depicted, including SMARTY.

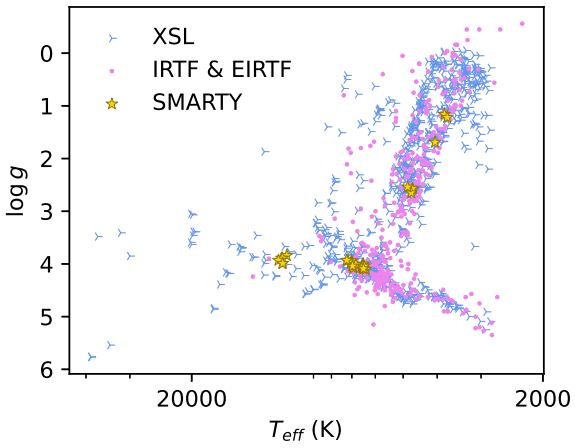

Figure 1. HR diagram for existent observed stellar spectral libraries in the NIR. In blue are the stars from XSL (Verro et al., 2022); in violet, from IRTF/E-IRTF (Cushing et al., 2005; Rayner et al., 2009; Villaume et al., 2017); and in yellow are the stars from SMARTY library.

Ensuring the quality of the spectra is crucial, given its foundational role in numerous applications. In view of this, as the SMARTY observations were made in poor weather, compromising the spectra quality, we made post-reduction flux corrections. First we normalized SMARTY spectra by adjusting polynomial functions to align its continuum and removing it, then we multiplied this normalized flux to the adjusted continuum of reference stellar spectra. We used three groups of reference spectra: *i*) the 5 control stars from other NIR libraries; *ii*) the interpolated (Vazdekis et al., 2003) IRTF stars with similar atmospheric parameters; *iii*) the theoretical spectra from Coelho et al. (2020) with matching parameters.

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The average difference between the 5 corrected spectra and their respective control spectra is 1%, which indicates a good quality for SMARTY spectra.

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Stellar population and emission line properties in S-PLUS galaxies with AlStar

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Keywords: *astronomical data bases: miscellaneous, galaxies, galaxies: stellar content, methods: data analysis, techniques: photometric*

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We present tests of a new method to simultaneously estimate stellar population and emission line (EL) properties of galaxies out of S-PLUS photometry. The technique uses the AlStar code, updated with an empirical prior which greatly improves its ability to estimate ELs using only the survey's 12 bands. The tests compare the output of (noise-perturbed) synthetic photometry of SDSS galaxies to properties derived from previous full spectral fitting and detailed EL analysis. For realistic signal-to-noise ratios, stellar population properties are recovered to better than 0.2 dex in masses, mean ages, metallicities and ±0.2 mag for the extinction. More importantly, ELs are recovered remarkably well for a photometric survey. We obtain input − output dispersions of 0.05–0.2 dex for the equivalent widths of [O II], [O III], Hβ, Hα, [N II], and [S II], and even better for lines stronger than ∼ 5 Å. These excellent results are achieved by combining two empirical facts into a prior which restricts the EL space available for the fits: (1) Because, for the redshifts explored here, Hα and [N II] fall in a single narrow band (J0660), their combined equivalent width is always well recovered, even when [N II]/Hα is not. (2) We know from SDSS that $W_{\mathrm{H}\alpha+[\mathrm{N\,II}]}$ correlates with [N II]/Hα, which can be used to tell if a galaxy belongs to the left or right wings in the classical BPT diagnostic diagram. Example applications of spatially resolved data are also presented. Comparisons of it with independent results obtained with MUSE data (also to integrated light with VST data) further confirm a good agreement for the properties.

In this work, we explore the potential of the S-PLUS data (Mendes de Oliveira et al., 2019). We have two kinds of comparisons: first our results with those from SDSS spectroscopy (Werle et al., 2019); and second our results from integrated photometry and datacube with those from VST and MUSE respectively. Figure 1 shows some RGB composites of stellar and nebular properties obtained with

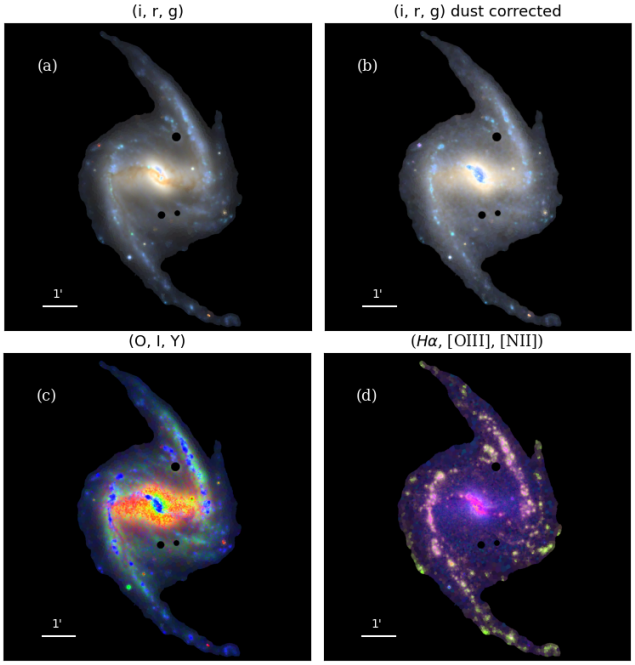

Figure 1. RGB composites combining respectively the (a) observed i, r, and g band fluxes, (b) the dust-corrected i, r, g fluxes, (c) the 5635 Å continuum fluxes associated with old, intermediate, and young populations, (d) the Hα, [O III], and [N II] fluxes.

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AlStar for the galaxy NGC 1365. The complete work is presented in Thainá-Batista et al. (2023).

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Parametric strong-lensing analysis of a high-disturbance galaxy cluster

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Keywords: *gravitational lensing: strong*

This contributed talk presented the method to model with Lenstool the strong lensing effect observed in the core of the massive galaxy cluster MACS J0159.0-3413 (hereafter M0159) at $z = 0.419 \pm 0.001$ (MUSE).

Strong lensing has become a prime tool for mapping the mass distribution of galaxy cluster cores. In the central regions of a galaxy cluster, the geometry of multiple-image systems and the distribution of the cluster members provide information on the priors for the matter distribution (Kneib & Natarajan, 2011). It is therefore more appropriate to use so-called parametric models.

To identify the cluster member galaxies (CMGs), a point source classification (Leauthaud et al., 2007) is done using the dual mode of the software SourceExtractor (Bertin & Arnouts, 1996) on the five HST filters of the cluster core. Then, the CMG candidates were selected by identifying the Red Sequence (RS) on a galaxy color-magnitude diagram (Gladders & Yee, 2000). CMGs are part of the RS, which has a width of (0.15 ± 0.05) mag. After a visual selection, 74 CMGs were included in the lensing potential. The lens redshift was identified from public MUSE data (ID 0100.A-0792, ESO-VLT-U4) with a M0159 BCG-centered FOV of $1' \times 1'$. Two multiple-image systems (8 multiple images) are visually identified by their color and morphology. The M0159 lens models done in this work are based on a previous model (Livermore et al., 2012), and were performed using the publicly available software lenstool (Kneib et al., 1996; Jullo et al., 2007). Image position predictions using lenstool was also done to confirm the presence of the lensed system 2 (see Fig. 1) for which we could not identify the redshift in the MUSE data.

In the lens models explored, each mass component is described by the dual Pseudo Isothermal Elliptical mass distribution (dPIE) (Limousin et al., 2005; Elíasdóttir et al., 2007):

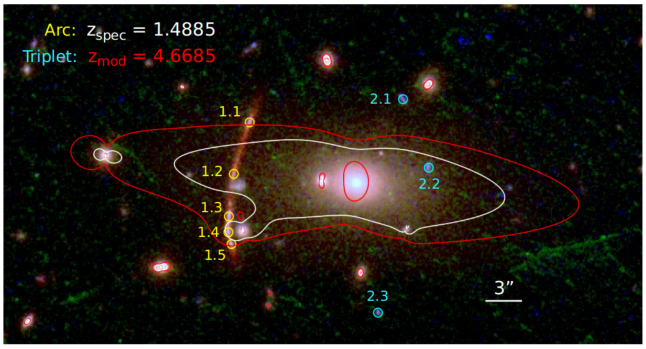

Figure 1. MACS J0159.0-3413 inner core. HST WFC3/IR F110W, F140W & F160W, and UVIS F606W & F814W. The circles show the positions of the multiple images. The white critical curve is computed at the spectroscopic redshift of the giant arc (z =1.4885, MUSE), while the redshift of the red critical line is a model's free parameter.

$$\rho(r) = \frac{\rho_0}{(1 + r^2/r_c^2)(1 + r^2/r_s^2)} \qquad (1)$$

where $\rho(r)$ describes the mass distribution of a spherical system with central mass density ρ_0, core radius r_c, and scale radius r_s. The number of free parameters is constrained by the limited number of spectroscopically-confirmed multiple images (five in this work). Thus, we cannot fit the parameters for each CMG individually. We do it instead for a typical $L^\star$ galaxy at the cluster redshift ($m_0^\star = 19.91$ in HST/WFC3 F814W), and the CMG parameters are assumed to scale relative to $L^\star$. Fig. 1 presents one of the lens models performed in this work.

We successfully map the mass distribution within the M0159 core, reproducing reasonably the observations. The model-predicted high-ellipticity of the central dark matter halo is assumed to be an artifact introduced by not

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considering in the models the merger-turbulence observed in optical, X-ray, and radio wavelengths (Cornil-Baïotto et al., in prep).

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Associations of dwarf galaxies in a ΛCDM Universe

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Keywords: *galaxies: dwarf, galaxies: kinematics and dynamics, infrared: diffuse background*

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Associations of dwarf galaxies are extended systems composed exclusively of dwarf galaxies. We study these particular systems in a Λ Cold Dark Matter cosmological model (ΛCDM), analyzing their intrinsic properties on the environment where they reside. We find that the velocity dispersion (σ) decreases systematically as the density of the environment decreases, ranging from $\sigma \sim 140$ km s^{-1} in knots to $\sigma \sim 20$ km s^{-1} in voids, provided that these systems are not gravitationally bound.

From the observational standpoint, associations of dwarf galaxies are identified in the Local Volume by Tully et al. (2006). In Yaryura et al. (2020), we investigate these systems within a ΛCDM model, finding that it effectively reproduces these systems and their main dynamical properties. As a continuation, in Yaryura et al. (2023), we characterize the environment where these systems reside using the eigenvalues estimated from the tidal tensor (e.g. Hahn et al., 2007) of the dark matter (DM) particle distribution. We conclude that associations located in more dense environments present significantly higher σ than those located in less dense environments, as long as these systems are not gravitational bound.

In this work, we extend Yaryura et al. (2023), but characterizing the environment using the eigenvalues estimated from the shear velocity (Hoffman et al., 2012) instead of from the tidal tensor. Figure 1 shows σ as a function of the total stellar mass of the dwarf galaxies association (M_{sys}). Coloured lines show median values while shaded regions cover from 25 to 75 per cent for each sample. Each colour corresponds to a different environment (knots, filament, walls and voids). Left panel shows that σ is highly influenced by the environment. When situated in voids, associations exhibit a low $\sigma \sim 20$ km s^{-1} , increasing up to $\sigma \sim 140$ km s^{-1} in knots. On the contrary, when we consider only gravitationally bound systems (Bound-Dwarf associations, right panel) the influence of the environment on σ is significantly reduced. It varies from $\sigma \sim 10$ km s^{-1} to $\sigma \sim 30$ km s^{-1}, with

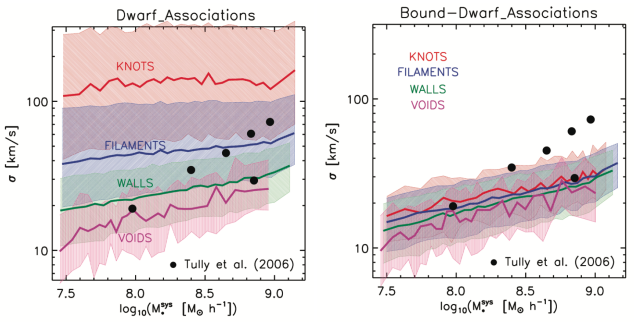

Figure 1. Left panel: Velocity dispersion (σ) as a function of the stellar mass of the association ($M_\star^{sys}$) for associations of dwarf galaxies. Right panel: Idem as left panel but considering only gravitationally bound systems. Black filled circles show observational results.

minimal variations based on the surrounding environment. Observed results presented by Tully et al. (2006) (black filled circles) are compatible with our results (left panel). Nevertheless, they are not compatible with our results when we consider only gravitationally bound systems (right panel). This would indicate that these observed associations could be non-gravitationally bound systems. These results are consistent with Yaryura et al. (2023), despite characterizing the environment in a substantially different way. In that case, we use the positions of the DM particles (tidal tensor), while in this work, we use their velocities (shear velocity).

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Constraints on modified gravity from follow-up observations of 20 Strong Lensing systems

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Keywords: *gravitational lensing: strong*

Strong Lensing (SL) systems can be used to set constraints on deviations from General Relativity (GR), quantified through the so-called Post-Newtonian parameter γ, which is equal to 1 in GR. In particular, for galaxy-galaxy SL systems, this can be done by combining the lensing derived mass modeling and the kinematics of the lens galaxy (obtained through the velocity dispersion σ_v). In this work, we present the first estimation of γ from purely ground-based data. To this end we conducted spectroscopic follow-up observations of systems selected from wide-field imaging surveys using the Southern Astrophysical Research (SOAR) and the Gemini Telescopes. In order to model these lenses, we employed the Source Lens and Lens (SLaM) modeling pipeline. With 20 strong lensing systems in our sample, we obtained a value of $\gamma = 1.13^{+0.21}_{-0.25}$, consistent with the value expected from GR at 68% confidence level.

Mass modeling of strongly lensed galaxy-galaxy systems is the backbone of different applications in cosmology. The SL modeling of such systems is generally carried out on space-based imaging data (usually from HST), strongly limiting the number of systems available for these studies. On the other hand, hundreds of thousands of these systems are expected to be discovered in the forthcoming Vera Rubin Observatory Legacy Survey of Space and Time (LSST Collett, 2015).

As a preparation for these upcoming data, our group has collected approximately 30,000 SL candidates, among which hundreds are expected to be suitable for modeling with available imaging from ground-based data. We refer to this comprehensive compilation of gravitational lenses as "the Last Stand Before Rubin" (LaStBeRu, Oliveira and Makler, in prep.). In order to derive γ from purely ground-based imaging data, we conducted follow-up observations of 20 lens systems selected from this sample on the SOAR and the Gemini Telescopes. The spectra where reduced with the standard pipelines and analysed using the `pPXF` (Cappellari, 2017) code to derive σ_v.

To model these systems, we have developed a semi-automated modeling pipeline that interactively reconstructs the noise-map and PSFs in the image cutouts available from the LaStBeRu compilation. The modeling is performed using an updated version of SLAM, which builds up upon Etherington et al. (2022). This pipeline consists of a multi-modeling connected layer in order to guarantee convergence during the lens parameters inference. Our best model fits the lens light as a Multi-Gaussian Expansion light profile, with a Power-Law density distribution. The source light is fitted by an adaptive pixelization in a Voronoi mesh. This pipeline is currently implemented using features of `PyAutoLens` (Nightingale et al., 2021).

We follow the analysis of Schwab et al. (2010) (see also Cao et al., 2017, and subsequent works) to combine the results from our SL modeling and our measurements of the lens velocity dispersion to set a constraint on γ. From our sample of 20 strongly lensed systems, we obtain a result of $\gamma = 1.13^{+0.21}_{-0.25}$, consistent with GR at 68% confidence level. Although the error bars are significantly larger than the current estimates in the literature, due to the sample size, these results show the potential for using ground-based data to test gravity. They are also the first constraints on γ from a sample entirely independent from the ones uses in the previous works.

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Investigating the extraplanar components in isolated late-type edge-on galaxies

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Keywords: *galaxies: evolution, galaxies: haloes, galaxies: ISM, galaxies: kinematics and dynamics*

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Some spiral galaxies featuring high star formation rates (SFR), show a major interstellar medium (ISM) phase extending kiloparsecs above/below the disc called extraplanar diffuse ionized gas (eDIG). Although several studies of this ISM phase have been conducted, there is still no consensus about the nature of its ionization source. We present scanning Fabry-Perot interferometer (FP) data from a sample of 14 nearby highly inclined late-type galaxies from the Catalogue of Isolated Galaxies (CIG, Karachentseva, 1973), which aims to serve as a baseline for comparison with interacting galaxies, providing insights into the formation and properties of eDIG.

Spiral galaxies viewed edge-on ($i \geq 80°$) unveil the vertical disc structure, exposing eDIG commonly found in galaxies with high SFR. Some studies have found as the primary driver of eDIG ionization regions mixed OB-shock and hot low-mass evolved stars (HOLMES) (e.g. Flores-Fajardo et al., 2011). While, recent integral field spectroscopy studies have agreed in that the eDIG may rather be a result of the circum-galactic medium (CGM) accretion (e.g. Levy et al., 2019; Tomičić et al., 2021; Bizyaev et al., 2022). FP data of a sample of isolated galaxies, key to studying structure with minimal environmental impact, would help to clarify the eDIG ionization source controversy.

We depicted the stellar disc structure by comparing the FP Hα monochromatic images with near-infrared (NIR) and ultraviolet (UV) images available in the literature. We detected eDIG in 11 galaxies of our sample which also presented extraplanar UV emission tracing an halo. In contrast to the general sample of highly inclined galaxies studied by Rossa & Dettmar (2003) (RD03), we do not observe indications that the environment influences the occurrence of eDIG (see Figure 1).

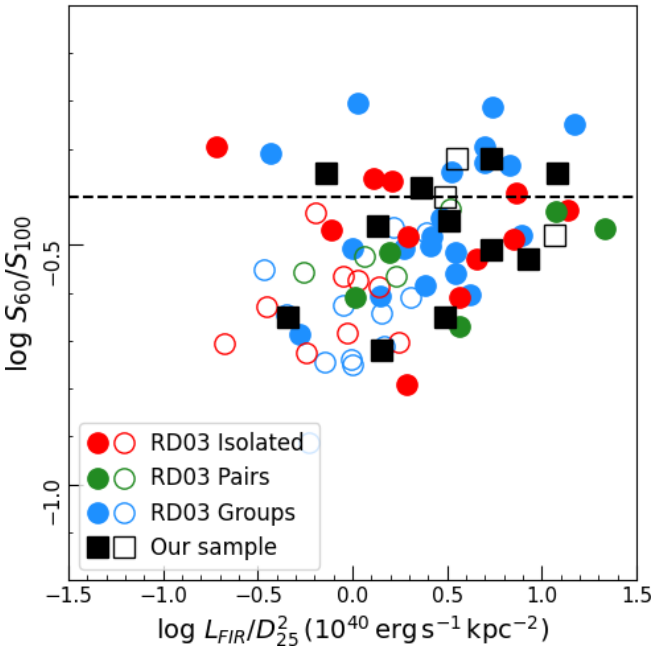

Figure 1. Comparison of RD03's sample with ours on the DIG Diagnostic Diagram (see RD03), distinguishing warm galaxies above the threshold at $S_{60}/S_{100} \geq 0.4$ (dashed line) tipically showing eDIG, considering the hierarchy and indicating the presence (filled markers) or absence (empty markers) of eDIG of both samples.

We analysed the FP Hα radial velocity and velocity dispersion maps, and we computed the rotation curves of galaxies in our sample. We also studied the rotation

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of the extraplanar component and the relation of the eDIG kinematical properties with several galactic integral properties such as stellar mass, SFR, maximum rotation velocity, dispersion velocity, etc. Preliminary kinematical results show that in isolated galaxies the amplitude of the rotational lagging increases with the SFR (see Sardaneta, 2021).

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Multiphase outflows in nearby active galactic nuclei observed with integral field spectroscopy

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Keywords: *galaxies: active, galaxies: ISM, galaxies: kinematics and dynamics*

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The feedback from Active Galactic Nuclei (AGN) plays a pivotal role in the evolution of galaxies. Winds emanating from AGNs have the capability to expel gas from galaxies or redistribute it throughout the interstellar medium. These winds are observed in multiple gas phases, and we have systematically undertaken a study of the molecular and ionized phases of these winds in nearby AGNs using integral field unit spectroscopy. Our observations reveal that, overall, the outflows effectively redistribute the gas within the galaxy.

Recognizing and describing the processes that change galaxies from actively forming stars to being quiescent is a fundamental objective in extragalactic astronomy. One crucial mechanism driving this transformation is galactic-scale feedback resulting from active nuclei (AGN). Supermassive black holes (SMBHs - 10^6-10^{10} $M_\odot$) form early (as indicated by the observation of distant Quasars, for example), and they co-evolve with their host galaxies (Gebhardt et al., 2000; Ferrarese & Merritt, 2000). The feedback from Active Galactic Nuclei (AGN) plays a significant role in the evolution of the most luminous galaxies, preventing them from becoming overmassive (Silk & Mamon, 2012)

AGN winds are hardly resolved by observations of distant galaxies, where the bulk of galaxy/supermassive black hole growth occurs, but they can be resolved in nearby active galaxies. Our group has been studying the AGN feeding and feedback processes over 15 years, using optical and near-infrared integral field spectroscopy of inner kiloparsec of nearby active galaxies obtained with large telescopes. These observations are used to spatially resolve the molecular and ionized gas emission structure and kinematics. We find that while outflows in ionized gas are seen in most objects studied, in molecular gas they are are less common, which usually is dominated by rotation in the disk of galaxies and shows inflows in some cases.

Figure 1 illustrates the relationship between the kinetic power of ionized outflows and the AGN bolometric luminosity, utilizing results obtained by our research group alongside a compilation from the literature. Drawing a parallel between simulated injected energy and measured kinetic power in outflows is akin to comparing apples to oranges, as it is improbable that all the simulated energy translates directly into measured kinetic power (Harrison et al., 2018). In addition, the multi-phase nature of the AGN winds must also be taken into account. We find than the velocity of the outflows are usually lower than the escape velocity of the galaxies, but they are efficient in redistributing gas within galaxies, which will still be available for further star formation.

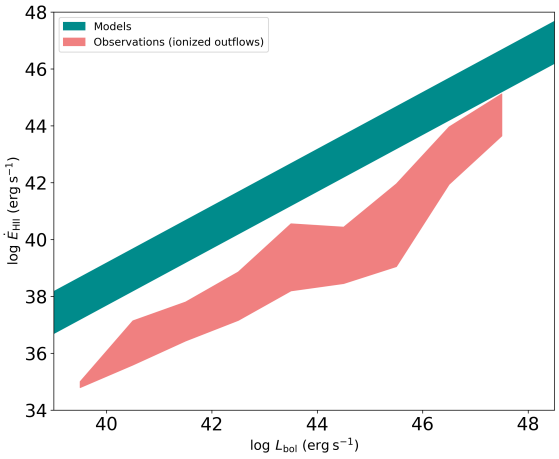

Figure 1. Plot of the kinetic power of the ionized outflows vs. the AGN bolometric luminosity using the data compiled by Riffel et al. (2023). The light red region depicts the average kinetic power of ionized outflows, along with the 1σ deviation, calculated within bins of 0.5 dex in AGN bolometric luminosity. The green region outlines the minimum efficiencies of outflow coupling required to effectively suppress star formation, as predicted by various simulations (Harrison et al., 2018).

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Dynamical analysis of galaxy populations in clusters

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Keywords: *galaxies: clusters: general, galaxies, galaxies: kinematics and dynamics*

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We analyze the velocity anisotropy profile, projected numerical density, and projected velocity dispersion profiles of four galaxy populations classified with respect to the main source of gas ionization: quiescent (Q), star-forming (SF), optical active galactic nuclei (AGN), and transition objects (T). Our results reveal that the Q population exhibits the highest degree of virialization, followed by AGN and T populations. In contrast, the SF population displays the most pronounced indicators of non-equilibrium.

Galaxies inhabit diverse environments, ranging from cosmic voids to dense galaxy clusters. It is well known that several galaxy properties vary according to the galaxy environment. In order to explain this observational trend various environmentally-drawn evolution mechanisms have been proposed in the literature (for a review, see Boselli & Gavazzi, 2006). The dynamics of galaxies within clusters provide insights into the relative efficiency of these processes. This analysis can be conducted using the Jeans equations, which allows one to access to the velocity anisotropy parameter, β, thereby offering information about the orbits of galaxies.

In this work, we analyze the $\beta(r)$ profile and the projected profiles of the numerical density $I(R)$ and velocity dispersion $\sigma_P(R)$ of four galaxy populations classified with respect to the main source of gas ionization. To accomplish this, we selected a sample of 143 galaxy clusters with $M_{200} \geq 10^{14.0} M_\odot$ and Gaussian velocity distribution in the line-of-sight, drawn from de Carvalho et al. (2017), including a total of 10974 galaxies with $0.03 \leq z \leq 0.1$ and $m_r < 17.78$. After creating an ensemble cluster with all galaxies, we utilize both the BPT (Baldwin et al., 1981) and WHAN (Cid Fernandes et al., 2011) optical diagnostic diagrams for the classification of galaxies into the following populations: star-forming (SF), optical active galactic nuclei (AGN), composite or transition objects (T, SF+AGN ionization), and quiescent (Q). The $\beta(r)$ profile is determined using both the MAMPOSSt code (Mamon et al., 2013) and the method of Solanes & Salvador-Sole (1990).

We find that galaxies belonging to the Q population exhibit the clearest indications of equilibrium within their respective clusters. Within this population, we observe the lowest values of velocity dispersion and clustercentric distances. The $\beta(r)$ profile for the Q population suggests a transition from more isotropic orbits near the center to increasingly radial orbits in the outskirts. On the other hand, the results for the SF population are consistent with a non-virialized population. SF galaxies tend to be situated in the outskirts, with this population displaying the highest values of velocity dispersion. In addition, the MAMPOSSt fails to identify an equilibrium solution for the $\beta(r)$ profile capable of reproducing the observed $\sigma_P(R)$ profile for SF galaxies.

The AGN and T populations exhibit comparable $\sigma_P(R)$ profiles, with AGN galaxies located in closer proximity to the central regions than T galaxies. The $\beta(r)$ profile for both populations indicates a transition from more isotropic orbits near the center to increasingly radial orbits. Moreover, MAMPOSSt's solution for the $\beta(r)$ profile effectively reproduces the $\sigma_P(R)$ profile of the AGN population and approximately that of the T population. These observations suggest that these populations are in a more advanced state of virialization in comparison to the SF population.

Our results are consistent with a scenario in which an infalling population composed of SF galaxies is affected by environmental mechanisms that remove their gas and redistribute their mechanical energy. This leads to the transformation of an outer SF population into a more central quiescent one. In this context, the T and AGN populations represent intermediate stages of this evolutionary process.

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How did dwarf galaxies end up compact?

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Using the IllustrisTNG-50 (TNG50) cosmological hydrodynamic simulation, we explore the evolution of the most massive progenitors of dwarf galaxies in order to understand how some of these galaxies end up compact. We split the TNG50 dwarfs into a control sample (*Normals*, that follow the the main trend in the z=0 size-mass relation) and in two compact populations: the lower envelope of this main trend (*Compacts*$_{\rm MB}$), and galaxies with stellar half-mass radius ($r_{1/2,*}$) lower than $\sim$ 450 pc (*Compacts*$_{\rm SB}$). We also divided our sample between those galaxies that end up as centrals and satellite galaxies. We explore the evolution of different galaxy parameters and compare between the populations to understand what drives the corpulence of compact dwarf galaxies.

In terms of the size ($r_{1/2,*}$) evolution, *Compacts* and *Normals* present similar sizes before $z \sim 0.8$, when the former population starts to shrink (top panel in Figure 1). We verify that, in the TNG50, this decreasing in size is related to a higher inner specific star formation rate (sSFR within $r_{1/2,*}$), especially for *CompactSBs* that present almost constant inner sSFR between $z \sim 1.7$ to ~ 0.45 (central panel in Figure 1). Besides the higher inner sSFR, *Compacts* present concentrated star formation (bottom panel in Figure 1): they form more stars within $r_{1/2,*}$ than in the outer regions.

In the first paper resulting from this work (De Almeida et al., 2024) we show that *Compacts* present a lack of mergers, especially at late times, related to a lower density environment. This allows an efficient gas infall that favors the concentrated star formation. In a future paper (de Almeida et al. in prep) we discuss the different scenarios for the dwarf satellite galaxies to become compact, which include concentrated star formation and also environment interactions (e.g. ram pressure and tidal stripping).

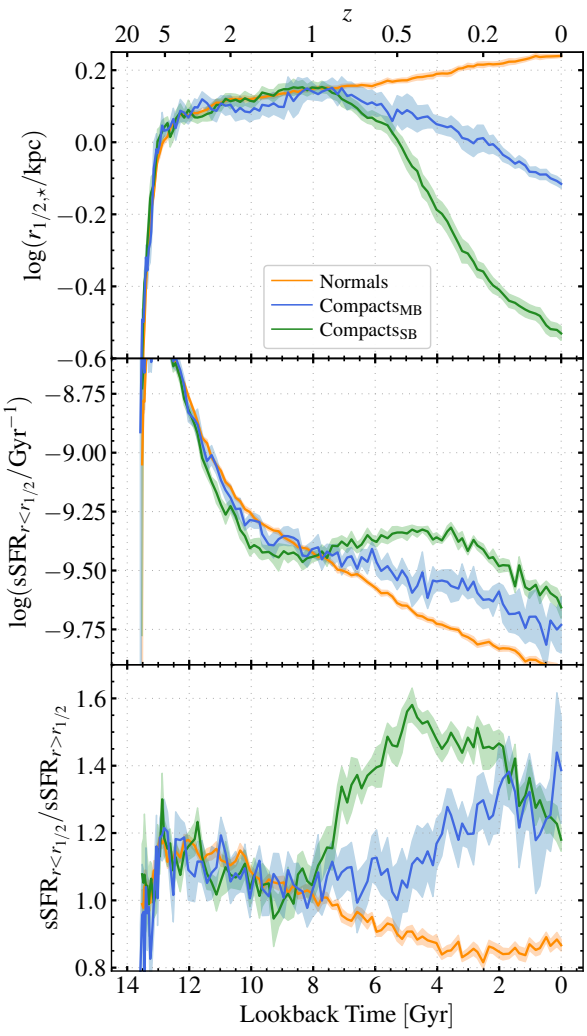

Figure 1. Median evolution of the stellar half-mass radius (**top**), inner sSFR (**center**) and inner over outer sSFR (**bottom**) versus lookback time; for the three populations.

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Acknowledgments

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Jellyfish galaxies and AGNs with HSC, DESI and PFS

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Keywords: *galaxies: structure*

Jellyfish galaxies are the most extreme cases of galaxies undergoing ram pressure stripping, and a possible link between them and AGN triggering has been suggested in the literature. We use HSC images and DESI spectra to search for jellyfish candidates and AGN hosts.

Galaxies residing in dense environments like clusters, groups, and filaments may undergo ram pressure stripping (RPS), losing gas from their disks (Gunn & Gott, 1972). In extreme cases, this results in asymmetric structures, resembling tentacles, known as "jellyfish galaxies" (Poggianti et al., 2017). RPS significantly influences galaxy evolution by potentially stripping most of a galaxy's gas, quenching its activity (Larson et al., 1980), yet it can also intensify star formation rates (SFR) during the process (Vulcani et al., 2020). Some studies suggest that stripping might trigger AGN activity, although it is still in debate (Peluso et al., 2023; Roman-Oliveira et al., 2019).

The distinct jellyfish morphology is primarily evident through the Hα emission. Our initial search targeted objects identified as probable Hα-emitters within the HSC-SSP data release 2. Specifically, we narrowed our selection to galaxies falling within the redshift range of $0.23 < z < 0.26$. This range ensures that the Hα and [N II] lines align within the NB816 narrow band. To improve accuracy, given the uncertainty of photometric redshifts, we exclusively considered galaxies with spectral observations in DESI. Our resulting sample comprises over 200 Hα-emitters, and our ongoing efforts are concentrated on pinpointing jellyfish galaxies and identifying AGN hosts among them. For that we are using the zooniverse for image classification, as well as BPT diagrams (Baldwin et al., 1981) and WHAN diagrams (Cid Fernandes et al., 2011).

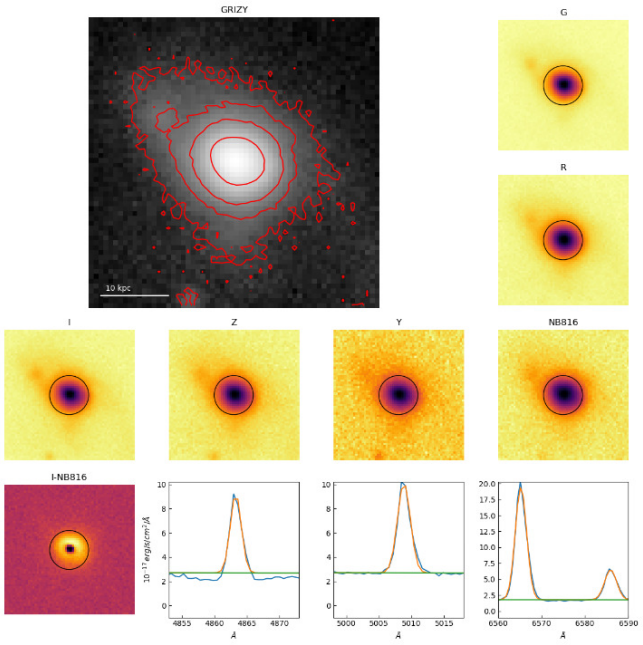

Figure 1. A stripping candidate in the ELAIS-N1. The multiple smaller figures show the fluxes in different HSC filters. The black circle in those stamps indicates the DESI's fiber aperture. The 3 graphs in the lower right show zoomed regions of the DESI spectrum of the emission lines Hβ, [O III]λ5007, Hα and [N II]λ6583, respectively.

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Microlensing scale estimation for 190 lensed quasars

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Keywords: *gravitational lensing: micro*

Gravitational lens occur when the light emitted for a background source is deflected by a mass potential in its path. One kind of configuration that has multiple cosmology applications and, in particular, is useful to study quasar structure is known as gravitational lens quasar, in which the source corresponds to a quasar and the lens corresponds to a galaxy. One of the problems for the strong lensing modeling of these systems is that the image fluxes could be affected by microlensing produced by stars in the lens galaxy. We present the automatic modeling of 190 systems to obtain an homogeneous modeled sample, and reduce systematic errors in lens parameters arising from different mass profiles. These models are used to estimate the microlensing timescales, i.e. the timescale in which the source crosses the Einstein radius of the microlens. We found median Einstein radius crossing time scales of 22 years, and median source crossing time scale of 8.5 months. This means that in $\sim$ 10 years part of the sources will be on the caustics (i.e. affected by microlensing), and the other part will be quiescent.

To estimate those time scales, we develop an automatic pipeline to model all known gravitationally lensed quasars. We used the photometry, astrometry, and redshift of each lensed quasar images as well as the lens galaxy (with assumed redshift in case it is unknown) to build our database and applied the software *LENSMODEL* (Keeton, 2011), well tested by the community. For each system, a summary of the steps in our pipeline is:

1. A mass distribution is selected based on the number of images of the system.
2. The model is accepted if the separation between the observed image positions and those estimated by the model are less than 0.01 arc seconds (median of the sample's astrometric errors).
3. If the model is accepted a Markov Chain Monte Carlo it is used to estimate the posterior of the parameters.
4. If the model is rejected, the next step is to increase its complexity by adding an external shear and return to step 1.

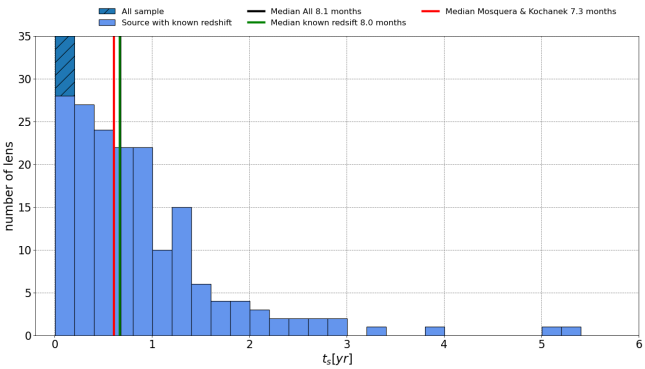

Figure 1. Histogram of t_S (unknown lens redshifts in dark blue) where the lines represent the median value obtained previously (red), the median for all the sample (black), and the the median for those systems with known lens redshifts (green).

The time scale, t_E, is defined as the time it takes the source to cross the Einstein radius of the microlens (R_E), defined as:

$$t_E = \frac{R_E}{v},\ R_E = D_{OS}\sqrt{\frac{4GM_\star}{c^2}\frac{D_{LS}}{D_{OL}D_{OL}}} \tag{1}$$

The other time scale is associated to short time variations, the so-called crossing time scale t_S, which is defined as the time it takes the source to cross its own diameter:

$$t_S = \frac{R_S}{v}, \tag{2}$$

being R_S the radius of the source and v the effective velocity of the source relative to the lens. This velocity has three components that correspond to the motions of the observer, the lens, and the source (see Mosquera & Kochanek (2011)).

We applied the analysis to a sample that is the double of previous studies, and obtained a median source crossing time of 8.5 months.

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Stellar population properties of massive compact galaxies at z ∼ 0: Evidence of diversity in the formation pathways

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Keywords: *galaxies: evolution, galaxies: formation, galaxies: stellar content*

We compared the stellar population properties of massive compact galaxies (MCGs) at low-redshift ($z \sim 0$) with average-sized quiescent galaxies (CSGs) matched in z. We showed differences in the stellar population properties at fixed effective velocity dispersion (σ_e), especially in the metallicity, where MCGs have lower metallicities than CSGs at fixed σ_e. Our results provide evidence about the formation and evolution of MCGs.

Quiescent galaxies are systems with low gas fractions, old and metal-rich stellar populations. The first quiescent galaxies are observed at $z \sim 4$. These galaxies are extremely compact at high z compared to their counterparts at $z \sim 0$ (van der Wel et al., 2014). Their small size and faint stellar continua make spectroscopic studies of large samples very challenging with current facilities, requiring alternative methods to investigate these galaxies. A possibility is to investigate local analogues as massive compact galaxies at $z \sim 0$.

To select the MCGs sample, we established a new criteria using the distances from the effective radii-σ_e and stellar mass-σ_e relations that were fitted to quiescent galaxies from the Sloan Digital Sky Survey (Abolfathi et al., 2018). For the final sample, we selected MCGs with $z < 0.1$, totalling 1858 MCGs. To compare properties of MCGs to typical quiescent galaxies, we selected a control sample (CSGs) of average-sized quiescent galaxies (5574 galaxies) matched in z.

We used the Penalized PiXel-Fitting (PpXF) code (Cappellari & Emsellem, 2004) with the Vazdekis et al.(2015) models (ages: 30 Myr - 13.5 Gyr, [M/H] −1.3 - +0.4, and [α/Fe] = BaseFe) and spectral indices to estimate mass-weighted ages, metallicities, and luminosity-weighted [α/Fe], following the methodology described in Schnorr-Müller et al. (2021).

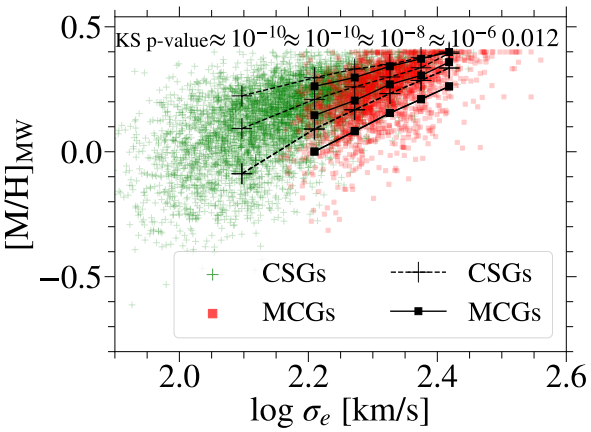

Figure 1. Metallicity as a function of σ_e to MCGs (red) and CSGs (green). The 16h, 50h, and 84h percentiles are showed in black squares (MCGs) and crosses (CSGs).

We compared the stellar population properties of MCGs and CSGs at fixed σ_e as previous works have shown that they correlate more tightly with σ_e than with other parameters such as stellar mass. At low-σ_e ($\sigma_e \leq 225$ km/s), MCGs are older and more α-enhanced than CSGs at fixed σ_e. At high-σ_e ($\sigma_e \geq 225$ km/s), MCGs and CSGs have similar ages and [α/Fe]. However, as shown in Fig. 1, MCGs have lower metallicities than CSGs in the entire range of σ_e.

Our results, taken together with the critical differences in the stellar mass at σ_e (CSGs are, on average, ∼ 0.7 dex more massive than MCGs of similar σ_e) indicate that MCGs and CSGs are descendants of different subgroups of the high z quiescent population. Lastly, we found that the metallicity of MCGs shows a dependence on stellar mass

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at fixed σ_e, while the age and [α/Fe] do not. These results can be associated with higher dark matter fraction within 1 effective radii (e.g. Graves & Faber (2010)). We suggest that this is possibly a signature of different quenching pathways followed by MCGs.

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Dark matter distribution in Milky Way-analog galaxies

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Keywords: *galaxies: haloes, galaxies: spiral, galaxies: kinematics and dynamics, infrared: diffuse background, (galaxies:) Local Group*

In this work, we combine HI spectroscopy with mid-infrared (mid-IR) imaging to investigate the dark matter (DM) distribution within Milky Way-analog galaxies. For that, our methods revolve in a three-dimensional dynamical modeling of atomic hydrogen (HI) data cubes to construct HI rotation curves (RC) and analyze the spatial distribution of the DM component. We then use an MCMC-based approach to separate the DM contribution and estimate the local DM density – an important value for DM direct detection experiments.

Our current understanding of how DM is distributed within the Milky Way (MW) halo, particularly in the solar neighborhood, is based on either careful studies of the local stellar orbits, model assumptions on the global shape of the MW halo, or from direct acceleration measurements. We here set out to use external galaxies in an attempt to go around some of these challenges.

Our MW-analog sample is comprised of 5 galaxies. Our galaxies were selected based on their HI velocity (200-280 km s^{-1}), morphology (typical Hubble T-type in the range of 2.0–3.0) and inclination ($35° < i < 75°$). We build RCs for each galaxy in our sample based on publicly available HI data from the THINGS and VIVA surveys (Walter et al., 2008; Chung et al., 2009) by using the three-dimentional dynamical modeling ^{3D}BAROLO (Di Teodoro & Fraternali, 2015). Our ^{3D}BAROLO run takes as free parameters the RC, velocity dispersion and position angle along the galaxy. With the aim of analyzing separately the DM and baryonic components, we further exploit available mid-IR data from the S^{4}G survey (Sheth et al., 2010). To separate the DM contribution from the RC and estimate the DM halo mass, M_{200}, and the halo concentration, c, we use an MCMC routine in PYTHON using 50 walkers and 30 000 iterations for each run.

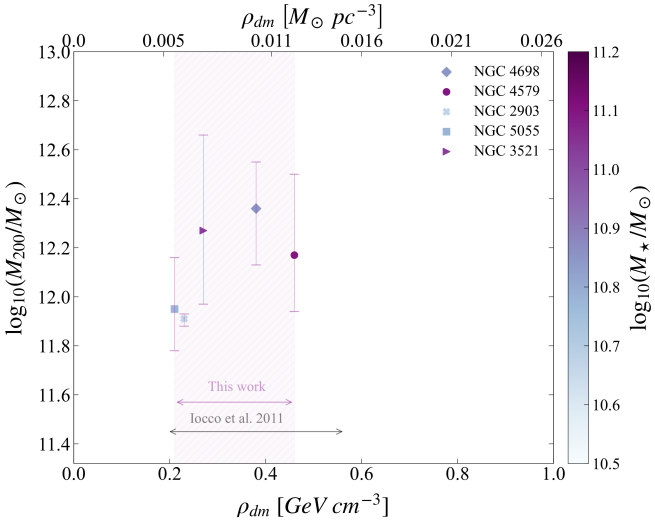

Figure 1. DM density estimates at the corresponding Sun's location (r/R_{25}=0.6) for our MW-analog sample. The error bars correspond to the 16th and 84th percentiles of the probability distribution function. Galaxies are colour-coded by their stellar mass. A complete description of this figure can be found in Gomes-Oliveira et al. (2023).

We measure the DM density at $r/R_{25} \sim 0.6$ (corresponding position of the solar neighborhood in external galaxies) for each galaxy in our sample. With values in the range of 0.21–0.46 GeV cm^{-3}, our estimates for the local DM density (ρ_{dm}) are in agreement with those from previous works in the literature with a focus on MW

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(see Table 3 of Gomes-Oliveira et al. (2023)). We show these values in Figure 1 as a function of the host DM halo masses.

By drawing a parallel with our own MW, this distinct approach based on external galaxies provides a potentially useful insight to the range of valid values for the local DM density. For a detailed look at this and other relevant results, we encourage readers to take a deeper look at Gomes-Oliveira et al. (2023).

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Automatic galaxy detection and measurement in large astronomical photometric surveys

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Keywords: *galaxies, galaxies: clusters, techniques: photometric*

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In images from the Southern Photometric Local Universe Survey (S-PLUS, Mendes de Oliveira C. et al. 2019), we aimed to detect galaxies previously reported in the literature as spectroscopically confirmed or probable members of the Fornax Cluster. Our goal is to properly detect the position and apparent size of the galaxies, which can appear excessively deblended, or not even be detected, in the original S-PLUS DR3 and DR4 catalogs. This happens because the `SExtractor` input parameters used to obtain the released catalogs are intended to provide useful data for both galactic and extragalactic purposes.

To achieve our goal, we worked with three different sets of `SExtractor` parameters (RUN 1, RUN 2 and RUN 3), suitable to automatically detect and measure different types of astronomical objects. To perform the `SExtractor` runs, we developed a publicly available pipeline (MESSI)[1] that allows us to automate the entire process. From these runs, we obtained catalogs with homogeneous photometry in the direction of the Fornax, Antlia and Hydra clusters, and in the STRIPE-82 zone. Besides allowing for different analysis of the sources located in those sky regions, these catalogs are being used in the context of the S-PLUS Fornax Project (Smith Castelli et al., 2022) and to select targets in the Fornax and Antlia clusters for the CHANCES project of the 4MOST collaboration (Haines et al., 2023).

The results of our work can be summarized as follows. In nearby (D< 50 Mpc) environments, S-PLUS DR4 `SExtractor` parameters are useful to automatically detect and measure galaxies displaying smooth morphologies that are not placed in the vicinity of bright objects. However, they tend to miss faint galaxies and compact objects near bright galaxies and to over-deblend star-forming galaxies. RUN 1 `SExtractor` parameters recovers faint objects near bright galaxies but it is not capable to solve the over-deblending issue in star-forming galaxies. On the contrary, RUN 2 avoids the over-deblending of low and intermediate luminosity star-forming galaxies and make a good characterization of the sizes of large early-type galaxies. However, they do not solve the problem of over-deblending in large star-forming galaxies. RUN 3 parameters avoid the over-deblending of large star-forming galaxies and improve the characterization of the sizes of large early-type galaxies in comparison with RUN 2. We explored the catalogs released by other photometric surveys and found that a strong over-deblending of nearby star-forming galaxies is also present in DECaLS (Dey et al., 2019) and J-PLUS (Cenarro et al., 2019). We also found that RUN 1, RUN 2 and RUN 3 parameter sets display the same performance as on S-PLUS images when applyed on DECaLS, J-PLUS and MiniJPAS (Bonoli et al., 2021) images.

From our results we conclude that catalogues released by large photometric surveys that have both galactic and extragalactic goals should be used with caution, at least in nearby environments, and that our sets of `SExtractor`

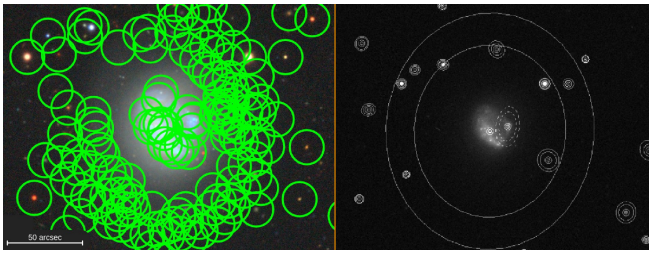

Figure 1. Example of an over-deblendend galaxy. In the left panel, the green circles indicate the multiple detections obtained by DECaLS. In the right panel we show the RUN 2 detections on the same galaxy.

[1] github.com/rodrihaack/MESSI

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parameters are useful to solve detection issues for different types of images.

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Cosmological applications of newly discovered gravitational lensed quasars

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Keywords: *gravitational lensing: micro, gravitational lensing: strong*

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Strong gravitational lensing is a useful tech- nique for examining astrophysical issues such as the general content and kinematics of the Universe. As variable sources, AGNs en- able measurements of the time delays be- tween images, which can be used to estimate absolute distances (i.e. an alternative tech- nique to constrain the Hubble constant). We present the results of an extended campaign of the Time Delay Cosmography collaboration to find new lensed quasars (brightest kind of AGNs), to produce reliable mass models and time delays.

The standard model of our universe (ΛCDM) depends on cosmological parameters associated to its components (such as dark energy, dark matter) and its expansion rate (associated to the Hubble constant, H_0). In recent years, the improvement in precision shows a discrepancy between the estimation of H_0 with data from the early and late universe (Di Valentino et al., 2021). This could be due to experimental (unknown) errors, or it could mean the need for an alternative model to ΛCDM (Efstathiou, 2021).

Strong gravitational lens provides an alternative technique to measure H_0. The gravitational lens phenomenon is produced when the light from a background quasar (source) is deviated by the gravitational potential of a foreground galaxy (lens), producing several images of the source (Schneider et al., 1992). Since the photons travel through different paths, they will reach the lens at separate times. The time lag between images (time delay, Δt) is inversely proportional to H_0:

$$\Delta t = \frac{1+z_L}{c}\frac{D_L D_S}{D_{LS}} F\Big(\frac{1}{2}|\vec{\theta}-\vec{\beta}|^2 - \psi(\vec{\theta})\Big) \qquad (1)$$

where z_L is the redshift of the lens, D represents the observer-source (D_S), observer-lens (D_L), lens-source distances (D_{LS}), and F is a function of the positions of the images ($\vec{\theta}$), and source ($\vec{\beta}$), and the gravitational potential ($\psi(\vec{\theta})$) of the lens. The angular diameter distance depends on H_0 and the selected model for the Universe (ΛCDM in this case).

A high precision measurement of H_0 requires accurate lens models and time delays (Birrer et al., 2020). Quadruply lensed quasars are preferred to doubles because they provide better constraints (4 image positions instead of 2, sometimes arcs) and 3 time delays per system (instead of 1). However, they are a rare event. The Time Delay Cosmography (TDCosmo[1]) has double the number of quads by discovering 30 new systems (Schmidt et al., 2023).

Accurate gravitational lens models requires high-resolution imaging in several bands (preferably from space), kinematic information for the lens to break the mass-sheet degeneracy problem (Falco et al., 1985) and to account for any perturbation from neighbor galaxies in the line-of-sight. Precise time delay measurements requires high precision photometry and high cadence in telescopes able to separate the images. Finally, using blind analysis, a combination of 6 known lensed quasars provides $H_0 = 73.3^{+1.7}_{-1.8} \mathrm{kms}^{-1} Mpc^{-1}$ (Wong et al. 2020), in agreement with other estimations from the late Universe.

To summarize, gravitationally lensed quasars is able to provide a high precision H_0 estimation. The combination of several systems helps to increase that precision and could solve the tension in H_0 between the early and late universe.

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On the nature of type 2 quasars

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Quasars and QSOs are the most luminous objects in the Universe, having bolometric luminosities $L_{bol} > 10^{46}$ erg/s produced by a Supermassive Black Hole (SMBH) with a high accretion rate in the nucleus of their host galaxies. The SMBH is surrounded by an accretion disk and emitting clouds with velocities in excess of 1000 km/s, surrounded by a dusty molecular torus at ∼pc scales. In the Unified Model of AGN (Active Galactic Nuclei), this torus blocks the view of the inner region if observed "edge-on", in the so-called type 2 QSOs. Type 1 QSOs, on the other hand, are supposed to be seen face-on and do not show obscuration. However, there has been some evidence suggesting that these two types of objects do not differ only due to orientation. The goal of this work is to investigate this for a QSO sample, comparing the optical spectral properties of QSO 1 with those of QSOs 2 using, in particular, the [O III] emission-line doublet for the quasar sample from SDSS DR 16, named DR16Q, to investigate a QSO 1 and 2 subsample within $0.4 < z < 0.5$. We found that the [O III] kinematic profile, traced by the W80 parameter, shows that the QSO 2 population has a broader profile than those for the QSOs 1. Moreover, the [O III] luminosity is higher for the QSOs 2 than for the QSOs 1. Both results suggest that there is a difference between these two QSO populations that cannot be fully explained by the AGN Unified Model. Our next step is to check if this difference persists up to $z = 1$ (when the [O III] doublet goes out of the SDSS wavelength range).

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Comparing stellar properties of cluster galaxies from z = 1 until today

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Keywords: *galaxy: general, galaxy: globular clusters: general, galaxies: evolution, galaxies: high-redshift*

The observed properties of galaxies are strongly dependent on both their total stellar mass and their morphology. Furthermore, the environment is known to play a strong role in shaping them. The galaxy population in the local universe that is located in virialized clusters is found to be red, poorly star-forming, and mostly composed of early morphological types (Pérez-Millán et al., 2023).

Towards a holistic understanding of the mechanisms that drive galaxy evolution, we exploit the data from the WIde-field Nearby Galaxy-cluster Survey (WINGS; $0.04 < z < 0.07$; Fasano et al. (2006)), and its extension OmegaWINGS (Gullieuszik et al., 2015). We also use the spectrophotometric code `SINOPSIS` (Fritz et al., 2007) to obtain galaxy properties such as stellar mass, Star Formation Rate (SFR) and Star Formation Histories (SFH), with the end to study the role of both the local and global environments affecting stellar properties at fixed morphology.

Using data from the ESO Distant Cluster Survey (EDisCS; $0.4 < z < 1.0$; White et al. (2005)), we compare our main results at low-z with those at intermediate-high redshift. We define our galaxy sample as cluster members with stellar mass $\log \mathcal{M}_*/M_\odot > 10$, and a good spectral fit obtained with `SINOPSIS` ($\chi^2 < 5$). The number of galaxies in the sample is 2,925 in WINGS/OmegaWINGS and 161 in EDisCS.

In Figure 1, we show the Main Sequence (MS) for star-forming galaxies in both low- and high-z samples. We observe the clear evolution of MS with redshift: the sSFR (SFR over stellar mass) of low-mass galaxies is about 1 dex higher in EDisCS than in WINGS/OmegaWINGS. According to Noeske et al. (2007), this reduction of sSFR for all stellar masses seems to be gradual, with gas exhaustion as the main candidate cause. Another important result is that the MS at high-z presents a steeper slope than at low-z, as also reported by, e.g., Karim et al. (2011), for the same redshift range we explore.

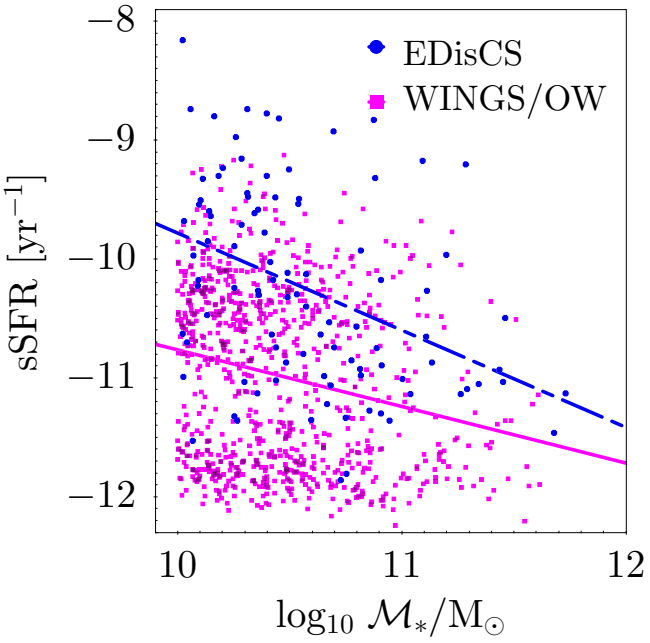

Figure 1. sSFR *versus* stellar mass. *Blue circles* and *short-long dashed line*: EDisCS; *magenta squares* and *solid line:* WINGS/OmegaWINGS. Lines represent the best linear fit. The main sequence of high-z galaxies is above the low-z main sequence at all stellar masses.

Among other results, we confirm some known findings, such as the morphological evolution through cosmic time and larger SFR at earlier epochs. We also determine that clusters may have been more efficient in quenching star formation in the past, and we propose that the general higher star formation activity in galaxies at these redshifts may explain the Butcher-Oemler effect. The paper with the full results will be published as Pérez-Millán (in prep.).

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Scientific results with the QUIJOTE-MFI wide survey: The anomalous microwave emission in our galaxy and M31

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Keywords: *cosmology, cosmology: cosmic background radiation, radiation mechanisms:general*

The detailed understanding of the Galactic emission processes in the frequency range from 1 to 3000 GHz is crucial for a state-of-the-art characterization of the Cosmic Microwave Background (CMB) anisotropies both in intensity and polarization. The Q-U-I JOint TEnerife (QUIJOTE) experiment is one of the current observational efforts devoted to study the CMB anisotropies and the microwave sky. The latter is dominated by four mechanisms: synchrotron, free-free, thermal dust and Anomalous Microwave Emission (AME).

The new QUIJOTE-MFI wide survey (Rubiño-Martín et al., 2023), covering the northern sky in the 10-20 GHz range, is useful for pinning down the AME spectrum at low frequencies. This allows a more reliable separation between the AME and other components than in previous analyses. In this talk we presented a brief overview of these aspects, with emphasis on the new results about the study of the AME in different environments (see Poidevin et al. (2023); Fernández-Torreiro et al. (2023, 2024); López-Caraballo et al. (2024)) coming from the recently released QUIJOTE data. For example, the AME emissivity ($\epsilon_{\rm AME}^{\rm 30GHz}$, in units of K/$\tau_{353}$) suggests a similar behaviour of the AME component in the Milky Way and M31 (on scales of 1°). We obtained 4.0 ± 2.7 for M31 (integrated SED, Fernández-Torreiro et al. (2024)) and values of $13.6^{+14.3}_{-6.9}$ (compact sources, Poidevin et al. (2023)) and $5.1^{+2.7}_{-1.6}$ (Galactic plane, Fernández-Torreiro et al. (2023)) for our Galaxy. Fig. 1 also displays the AME emissivity reported by Harper et al. (2023) (CBASS data) and the estimated from Battistelli et al. (2019) (SRT data at 25 GHz) for M31.

Finally, we also presented the status of the QUIJOTE MFI2 instrument (Hoyland et al., 2022), the upcoming upgraded version of the former MFI instrument. We expect

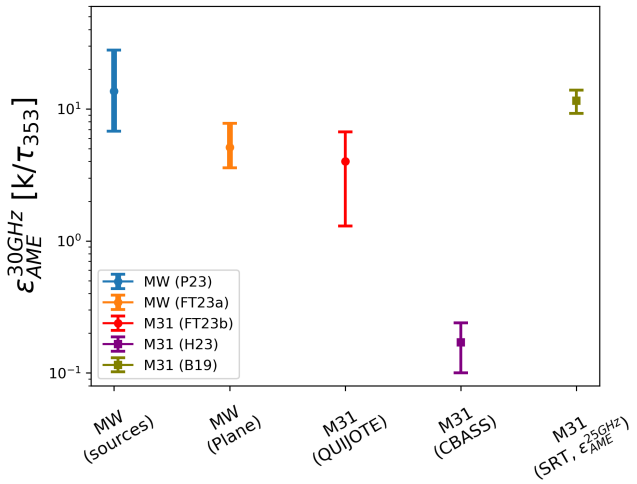

Figure 1. The Milky Way AME emissivity obtained from the statistic of compact sources (Poidevin et al. (2023), blue) and diffuse emission from the Galactic plane (Fernández-Torreiro et al. (2023), orange). For M31, measurements are recovered from the integrated spectral energy distribution (Battistelli et al., 2019; Harper et al., 2023; Fernández-Torreiro et al., 2024).

to improve the sensitivity by a factor 2–3 with respect to the MFI. The MFI2 has a digital FGPA (Field Programmable Gate Array) based back-end to improve the radio frequency interference (RFI) removal. MFI2 commissioning will take place at the beginning of 2024, while the implementation of the FGPA system is expected for the next year.

The MFI2 instrument will be used in the second phase of the future European Low Frequency Survey (ELFS) collaboration, in the Simons Array telescope (Aniello & et al., 2023). ELFS aims to characterize the southern

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sky from the Atacama desert (Cerro Toco, Chile) on scales of ∼10 arcmin covering the frequency range 5–120 GHz. This project will be in synergy with other CMB experiments located in the Atacama desert such as the Simons Observatory (The Simons Observatory Collaboration et al., 2019; Aniello & et al., 2023).

The QUIJOTE-MFI wide survey maps and derived data products can be found at https://research.iac.es/proyecto/quijote.

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Ionized gas kinetic feedback in MaNGA AGN

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Keywords: *galaxies: active, galaxies: kinematics and dynamics, galaxies: nuclei*

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We study 293 Active Galactic Nuclei (AGN) host galaxies and 485 control galaxies from MaNGA-SDSS, we analyzed the ionized gas kinematics using [O,III]λ5007Å, emission line profiles. We observed a positive correlation between $\langle W_{80}\rangle$ and L[O,III] for AGN. We define and we obtain the extent of the Kinematically disturbed regions that is about 55% of the Extended Narrow Line Region in mean. We find that the low-luminosity AGN impact on the host galaxy in a "maintenance mode" feedback.

Powerful AGN exhibit observable interactions with surrounding gas, manifesting as kinetic disturbances like outflows or enhanced velocity dispersion, particularly perpendicular to radio jets and ionization axes. The kinetic feedback on AGN surrounding gas is a complex, multi-phase phenomenon, with various gas phases observable in different spectral domains (Roy et al., 2021). In this study we investigate the ionized gas kinematics, in a sample of 293 AGN host and 485 control galaxies observed by MaNGA-SDSS project, where each AGN was paired with two controls, so that the redshift, inclination, morphology, mass stellar are similar. The criteria of the sample select are described in Rembold et al. (2017). We measurements the W_{80} values (Liu et al., 2013) in the [O III]λ5007Å emission line profiles, fitted with one narrow Gaussian component in the whole sample, except for 45% of the AGN sources with one additional broad component. The distribution of the weighted mean $\langle W_{80}\rangle$ values has a median value of 453 km s^{-1} for the AGN and 306 km s^{-1} for the controls. The median difference in the W_{80} values between AGN and its controls is 143 km s^{-1}. we attribute these larger W_{80} values in the AGN to kinematic disturbances in the gas by the AGN: its radiation pressure, heating and/or outflows (Riffel et al., 2021). We also find a positive correlation between the $\langle W_{80}\rangle$ and L[O III] fo the AGN, strengthening when combined with control galaxy values, indicating that the AGN luminosity plays a dominant role in introducing kinematic disturbances and outflows in the host galaxies (Wylezalek et al., 2020).

We identify the Extended Narrow Line Region (ENLR) and the "kinematically disturbed regions" (KDRs) of the AGN, characterized by $W_{80} \geq W_{80,cut} = 315$ km s^{-1} – the mean value for the controls plus its standard deviation. The median of this extents are R_{KDR}=4.3 kpc and R_{ENLR}=8.4 kpc, showing that, typically, the extent of the KDR is about 55% that of the ENLR region, like found in previous studies as in Deconto-Machado et al. (2022).

Finally we estimate the ionized gas mass outflow rate ($\dot{M}_{out}$) and the corresponding kinetic powers ($\dot{E}_{out}$) assuming that the KDR is due to an AGN outflow. Using two methods to obtain the outflow velocity — one based on W_{80} and the other using the velocity of the broad component, we find the following mean values: $\langle \dot{M}_{out,W_{80}}\rangle$ =1.92±0.09×10^{-3} $M_\odot$ yr^{-1} and $\langle \dot{M}_{out,b}\rangle$ =3.59±0.014×10^{-3} M$_\odot$ yr^{-1} for the mass outflow rate;$\langle \dot{E}_{out,W_{80}}\rangle$ = 1.74 ± 0.71 × 10^{38} $erg\,s^{-1}$ and $\langle \dot{E}_{out,b}\rangle$ = 4.57±0.13×10^{38} $erg\,s^{-1}$, for the outflow powers. The kinetic powers for the outflows that correlate with the AGN luminosity L_{bol}, populating the low luminosity region of this known correlation. This correlation corresponds to a coupling efficiency between the outflow power and AGN luminosity of 0.01% and lower. But the large extent of the KDR, in spite of this low coupling efficiency, shows that even low-luminosity AGN, as those of our sample, can impact the host galaxy in a low, “maintenance mode" feedback.

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Exploring late-time physics to explain the Hubble tension

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Keywords: *cosmology, cosmology: cosmological parameters, dark energy*

In this work we analyze Type Ia supernovae (SNe Ia) data from the Pantheon+ compilation (Scolnic et al., 2022) to investigate late-time physics effects that impact the expansion history, $H(z)$, at low redshifts ($z < 2$). Dynamic Dark Energy (DE) models allow for increased acceleration of the expansion at late times while preserving the physics of the early universe, consistent with Cosmic Microwave Background (CMB) results. We focus on a late DE model that introduces a deviation in the DE equation of state, w_0, at a specific redshift, z_a, by means of a Dark Energy Sigmoid model as described by Torres-Arzayus et al. (2024). The fit results are: $H_0 = 73.3^{+0.2}_{-0.6}$ km s^{-1} Mpc^{-1}, $w_0 = -0.95^{+0.15}_{-0.02}$ and $z_a = 0.8 \pm 0.46$.

The Hubble tension refers to the 5σ discrepancy in the values of the Hubble constant, H_0, derived from CMB data and those measured from the magnitude-redshift relation using standard candles (Di Valentino et al., 2021). The late DE mechanism proposed here employs a sigmoid function to describe the dark energy equation of state, $w(z)$, transitioning from $w_a = -1$ for $z > z_a$ to w_0 for $z < z_a$, as follows:

$$w(z) = w_0 + \frac{w_a - w_0}{1 + e^{\left(\frac{z_a - z}{r}\right)}}. \quad (1)$$

The equation above describes a smooth transition taking place at a redshift centered around z_a with a transition rate r. The value of w_a is set to -1 to ensure that at high redshifts the universe's dynamics adhere to the standard ΛCDM. A Monte Carlo code was developed to generate synthetic SNe compilations at the same redshifts of the Pantheon+ SNe subset used in the main fit, and using a nominal SN magnitude error $\sigma_m = 0.2$ (the average magnitude error). For each realization, the Monte Carlo loop generates randomized magnitudes with σ_m Gaussian width, and using an underlying sigmoid model with true parameters (w_0, z_a) set equal to the best fit values. For each Monte Carlo realization, the fit code was executed and a corresponding set of (w_0, z_a) best fit parameters obtained. The 68% and 95% CL contours of the Monte Carlo points on the (w_0, z_a) plane are shown in Figure 1.

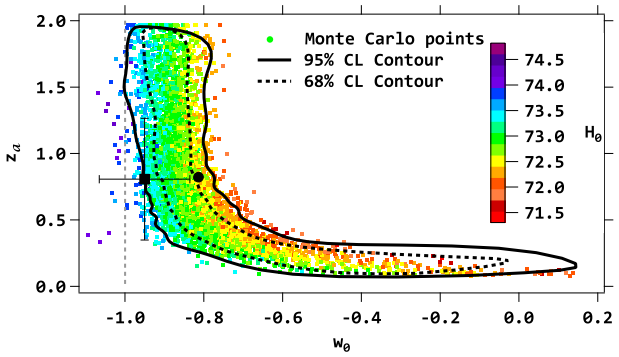

Figure 1. 95% and 68% CL contours for Monte Carlo points. The color coded points on the (w_0, z_a) plane are each one the result of a fit to a randomized realization of SN magnitudes at the same redshifts as the sample used for the main analysis (Torres-Arzayus et al., 2024). The Color scale represents the corresponding H_0 values. The black square with error bars is the best fit sigmoid DE model, the round circle is the Monte Carlo average.

The fit to the sigmoid DE model is slightly better, but not statistically significant, than a fit to the baseline ΛCDM model. The sigmoid model is not rejected by the data and identifies a specific redshift, $z_a = 0.8$, where a potential transition in the equation of state could have occurred. As can be seen in Figure 1, the sigmoid model does not favor a DE in the phantom region ($w_0 < -1$). While the sigmoid DE model does not completely resolve the H_0 tension, it offers a transition mechanism that can still play a role along side other potential solutions.

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Characterizing Hα emitters in the Fornax galaxy cluster with S-PLUS

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The Fornax cluster is a remarkable environment to investigate emission line galaxies in high density environments. The narrow band filter J0660 of the Southern Photometric Local Universe Survey (S-PLUS), used as an input of our own code P.E.L.E. (Pixel-to-pixel Emission Line Estimate), allow us to create Hα+[NII] emission maps for the Fornax galaxy members. From these maps, we are able to characterize the Hα+[NII] emitters in relation to their morphology, spatial distribution within the cluster and their location in the phase-space diagram.

P.E.L.E. (Lopes et al., in prep.) is a python script that uses the combination of three images (r, J0660 and i in the case of S-PLUS) to build pixel maps highlighting Hα+[NII] emission. This software follows an automatic procedure that downloads the images from the splus.cloud database, performs their photometric calibration and a point-spread function correction, masks the stars based on an independent run of SEP (Source Extraction and Photometry, Barbary 2016) and applies the Three Filter Method (e.g. Vilella-Rojo et al. (2015)) resulting in an Hα+[NII] map. The methodology was validated by the comparison with the derived Hα maps from Iodice et al., 2019 (hereafter I19) based on VLT/MUSE data (Smith Castelli et al., submitted). It is found that P.E.L.E is able to recover all emission signal down to 10^{-17} erg s^{-1} cm^{-2} per pixel in the 13 objects discussed by I19.

From 213 spectroscopic confirmed members of Fornax, 79 emitters were identified. After a visual inspection, 28 galaxies were classified as spirals (S), 21 as ellipticals or lenticulars (Early-type), and 30 as irregulars or with a disturbed, peculiar shape (Irr). Figure 1 shows that all Early-type emitters are located inside an area of 3 virial radii ($R_{\rm vir}$) of the cluster (Fornax $R_{\rm vir} \sim 0.7$ Mpc ~ 2 deg), while the late-type sources extend outwards. Moreover, a number of emitters can be seen inside the Fornax A subgroup ($R_{\rm vir} \sim 0.35$ Mpc ~ 1 deg) but only one of them displays an Early-type morphology. Alternatively, an analysis of the projected phase-space diagram reveals that the majority of Irr emitters within 3 $R_{\rm vir}$ are recent infallers, i.e., they fell into the cluster less than 1 Gyr ago. Such results agree with the scenario in which recent infallers still preserve disturbed morphologies.

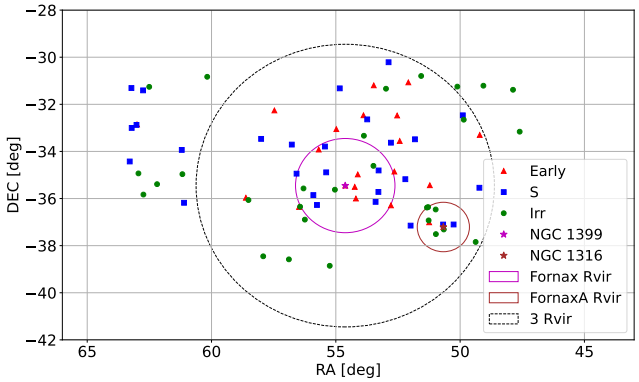

Figure 1. Spatial distribution of 79 Hα+[NII] emitters detected by P.E.L.E. and color coded according to their morphologies (spirals: S; early-type galaxies: Early; irregular/disturbed/peculiar objects: Irr). The magenta and brown solid lines represent the virial radius of Fornax and Fornax A, respectively.

In order to further explore the morphological characteristics of the selected objects, a study using Morfometryka (Ferrari et al., 2015) is under development.

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The goal is to improve our current classification by using different morphometrical parameters, such as sersic index, asymmetry and concentration, among others, in the 12 filters of S-PLUS. In addition, we expect that the combination of our Hα+[NII] maps with data in other wavelengths (e.g. HI) provides some clues about the physical processes the galaxies are currently undergoing in Fornax.

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Star formation history of stellar systems in an intermediate-age merger remnant

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Ultra-compact dwarfs (UCDs, Hilker et al. 1999) are a type of compact stellar system that lies in the mass-size parameter space between globular clusters (GCs) and compact elliptical galaxies (cEs). Although their physical properties do not have a precise definition, we could say that in a broad sense they are objects with M_V < -9 mag, stellar masses >10^6 $M_\odot$ (Forbes et al., 2020) and effective radii between 3 and 100 pc (Wittmann et al., 2016). Thus, UCD includes both massive GCs and nuclei of tidally stripped dwarf galaxies; in some cases, differentiating between them is not trivial.

In Sesto et al. (2018) we conducted a spectroscopic analysis of the GC system's inner zone associated to the intermediate-age merger remnant NGC 1316, based on multi-object spectroscopy obtained with the Gemini/GMOS camera. Currently, we are analyzing the most relevant physical properties of the different stellar systems associated with this galaxy, with the aim of classifying them as massive GCs or stripped nuclei of dwarf galaxies (Sesto et al., in prep.). In this work, we have focused on the behavior of two objects in our sample, which in addition to being intrinsically bright, had been reported as extended GCs by Norris et al. (2014). As a first step, we measured the effective radii using the ISHAPE profile-fitting code (Larsen, 1999), using images from the HST archive. This technique convolves the stellar Point-Spread Function with a presumed analytical model profile. This analysis confirmed that these are two extended objects, whose radii are larger than expected for a classical GC. Secondly, we determined their star formation history (SFH) using the full-spectrum fitting technique, with the code pPXF (Cappellari & Emsellem, 2004). This method finds the best combination of synthetic simple stellar population (SSP) models in order to fit the entire observed spectrum. We selected the SSP models from MILES libraries (Vazdekis et al., 2010), which cover an age range from 0.03 to 14 Gyr, metallicities $-2.27 < [Z/H] < 0.4$ dex, and values of [α/Fe]=0.0 and 0.4 dex. We recovered the average of mass-weighted age and metallicity with pPXF by fitting 100 Monte Carlo realizations (see Figure 1). Finally, considering age and metallicity values previously obtained, we have estimated stellar masses assuming mass-to-light ratios from the SSP models of Maraston (2005).

ID	M_V (mag)	radii (pc)	Age (Gyr)	[Z/H] (dex)	Mass (M_{sun})
728	-11.65±0.009	12.5±0.8	1.9±0.3	0.26±0.1	4.5×10^6
636	-10.05±0.005	5.1±0.7	3.4±0.4	0.05±0.1	2.7×10^6
			11.1±0.7	0.05±0.1	

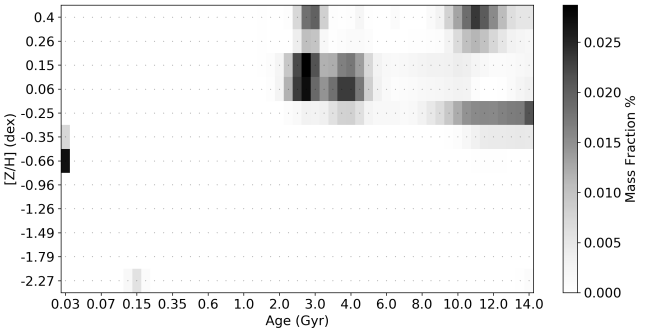

Figure 1. Top panel: the table displays the results obtained for the two stellar systems analyzed in this study. Bottom panel: mass-weighted age-metallicity diagram for ID=636, which allows the visualization of their SFH. The gray-scale represents the mass-weighted value assigned by pPXF to each SSP model.

All this information together (see table) seems to indicate that our sample is made up of objects of a different nature. On the one hand, we have a young, extended, and massive GC, which has formed the bulk of its stars in a single event (ID=728). On the other hand, we have a not-so-massive and extended object, with a complex SFH, which seems to indicate a galactic origin (ID=636).

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The Next Generation Fornax Survey (NGFS)

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Keywords: *galaxies, galaxies: clusters, galaxies: dwarf, galaxies: evolution, galaxy: formation*

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The Next Generation Fornax Survey (NGFS) targets all baryonic structures down to GC masses within the virial sphere of the Fornax galaxy cluster, utilizing the optical bands u', g', and i' in conjunction with the near-infrared (NIR) J and K_s filters.

The NGFS uses an intricate observing technique to reach deep surface brightness limits that allows us to detect ultra-low surface brightness dwarf galaxies down to $\mu_{i'} \simeq 29-30$ mag/arcsec^2 (Muñoz et al., 2015; Ordenes-Briceño et al., 2018a). Using the observing efficiency of DECam on the Blanco telescope at CTIO, complemented by NIR observations from VIRCAM on the VISTA telescope at ESO, we have secured large samples of galaxies to conduct volume-limited studies of their scaling relations. We find that galaxies form in three mass domains: 1) central core accretion in dwarf galaxies ($\log \mathcal{M}_\star \lesssim 8$), 2) homologous growth in intermediate-mass galaxies ($8 \lesssim \log \mathcal{M}_\star \lesssim 10.5$), and predominant halo mass assembly in massive galaxies ($\log \mathcal{M}_\star \gtrsim 10.5$; for details see Eigenthaler et al., 2018). Furthermore, we find a bimodal scaling relation between the masses of the nuclear star cluster and their host galaxy spheroid (Ordenes-Briceño et al., 2018b). While dwarf galaxies with masses $\log \mathcal{M}_\star \lesssim 8$ show an anticorrelation between $\eta = \mathcal{M}_{\rm nuc}/\mathcal{M}_{\rm gal}$ and the galaxy mass, the higher mass galaxies show a positive correlation. We speculate that a mixture of in-situ formation and accretion mechanisms is at play without clear support from current theoretical predictions.

New results based on the Hα-imaging extension of NGFS show intriguing, localized recent star-formation activity in galaxies. In particular, dwarf galaxies show both Hα absorption and emission signatures in their central regions. The depth and spatial resolution of the Hα imaging data allows us to resolve the star-formation (SF) properties of NGFS galaxies. We find that while the integrated Hα properties of galaxies align well with the standard SF scaling relations of galaxies (e.g. Peng et al., 2010), there is significant variance of the SF-ing regions in individual galaxies (up to 6 orders of magnitude).

Our most recent analyses related to the dynamical properties of satellite galaxies in the Fornax galaxy cluster identified a distinct transition radius, demarcating two zones where satellites exhibit varying properties of tidal

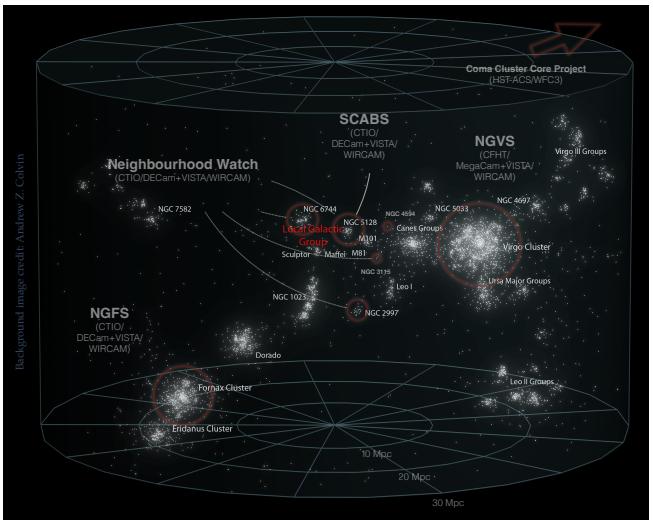

Figure 1. Surveys targeting the most important baryonic overdensities in the Local Universe (within 30 Mpc) studied by our research team. Note that the Coma galaxy cluster lies at a distance of about 100 Mpc (background image credit: Andrew Z. Colvin, licensed under the CCA-Share Alike 3.0 Unported license).

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stress. Intriguingly, this substructure mirrors patterns observed in cosmological galaxy simulations. Furthermore, when examining diverse cosmic environments, we discern a comparable transition radius in the Virgo galaxy cluster, as well as among the satellite galaxies of both the Milky Way and Andromeda (Blaña et al., in prep.).

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Probing outskirts of accretion disks through O I λ11297 broad emission line of active galactic nuclei

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Keywords: *accretion: accretion disks, line: profiles, techniques: spectroscopic*

We report the first detection of a double-peak broad emission line in the near-infrared region (NIR) associated with the O I λ11297 emission in the Seyfert 1 galaxy III Zw 002. Simultaneously, we detected double-peak emission in the Paα line. We reproduce the observed profile due to a disk inclined by 18°, with a maximum emission radius of 52.43 lt-day. This work marks a significant step in understanding the accretion disk outskirts in active galactic nuclei (AGNs).

The phenomenon of double-peaked broad emission lines (DPBELs) has been extensively studied in optical spectra. They are most commonly detected using optical spectroscopy in the Balmer lines and interpreted as evidence for the presence of an accretion disk. Previous studies have highlighted persistent features in the Hβ line of III Zw 002 (Mrk 1501 or PG 0007+106), with evidence of both blue and red asymmetries in the line profile. Grier et al. (2017) revealed a persistent redward feature in the Hβ line, consistent with a disk model, while Popović et al. (2003) observed both blue and red asymmetries, suggesting a disk model combined with a Gaussian component. Despite the extensive variability observed across various wavelengths, the near-infrared (NIR) region has remained largely unexplored for III Zw 002.

The NIR spectrum of III Zw 002 was captured on July 28, 2021, using the GNIRS spectrograph at the Gemini North telescope. The setup covered a 0.8–2.5 μm spectral range with a resolution of 1700. The observations consisted of eight 150s exposures. The telluric star A0V HIP186 was observed at an airmass of 1.052. The analysis confirmed the double-peaked nature of III Zw 002 and revealed double-peaked profiles in Paα and OIλ11287 lines. The data reduction process is detailed in Dias dos Santos et al. (2023). The NIR spectroscopy allowed us to simultaneously detect double-peaked profiles in different lines emitted by the BLR of III Zw 002 and set important constraints on the size and geometry of the accretion disk of such AGN.

The double peak profiles were fitted using a disk-based model (Chen & Halpern, 1989), with an additional Gaussian component referred to as non-disk clouds, representing the classical broad line region (BLR). We derive the disk inclination, a key parameter for estimating the virial factor (f, see e.g., Panda et al. (2019)). Utilizing measured inclinations and various values of gas distribution (κ) representative of the disk geometry, we obtain virial factors consistent with those of other AGNs, supporting the reliability of our method.

Furthermore, the fit analysis indicated that the disk is geometrically more extended in O I (up to 18.86 ld-day) than in Paα (16.77 ld-day), meaning that the lines originate from slightly different maximum emissivity radii. This result corroborates several works that have demonstrated through kinematic and photoionization models that the O I line originates in the outer portion of the BLR (Martínez-Aldama et al., 2015). The interpretation of our findings points out that both emission lines originate in a BLR distribution of clouds dominated by a planar geometry, with orbits well described by those of a Keplerian disk. The result provides a comprehensive understanding of the BLR dynamics in III Zw 002 and sheds light on the underlying mechanisms driving its peculiar emission line profiles.

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The QU Bolometric Interferometer for Cosmology: status and prospects

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QUBIC is an bolometric interferometer telescope installed at the Puna, in the Salta province of Argentina, to measure the polarization of the CMB, searching for the CMB primordial B modes, that will be an indirect evidence of the inflationary period of the Universe. Here, we update on its current status and prospects.

The Q&U Bolometric Interferometer for Cosmology (QUBIC, Hamilton et al., 2022) is the first bolometric interferometer designed to measure the primordial B-mode polarization of the Cosmic Microwave Background (CMB). Bolometric interferometry (BI) is a novel technique that combines the sensitivity of bolometric detectors with the ability to control the systematic effects enabled by the interferometry. Both sensitivity and systematic control are very important since the primordial B-modes is a very faint signal. Thanks to the frequency dependence of its synthesized beam, QUBIC presents a unique feature, the so-called "spectral imaging", i.e., the ability to recover the sky signal in several sub-bands within the physical band during data analysis. This feature provides an in-band spectral resolution of $\Delta\nu/\nu \sim 0.04$ that is unattainable by a traditional imager. This is a key tool for controlling the Galactic foreground's contamination.

Since its inauguration, QUBIC has been in commissioning stage, during which, several studies related to the calibration of the instrument have been carried out. Since the telescope is unique in its design and architecture, all the pipelines had to be specifically developed for those purposes. Studies such as the corrections of flux jumps, the measurement of time constants of the detectors, the angular resolution at different frequencies, and more, have been carefully carried out. Many of these studies were published in eight papers for a special edition of JCAP (2023), and other articles are currently in preparation.

It is known that multi-frequency observations are needed to constrain galactic foregrounds and isolate the CMB signal. Many experiments are designed in several spectral bands to have information at different frequencies. Also, there are many methods in the literature to perform the component separation. QUBIC will allow to do the component separation at the map-making level (Regnier & et al., 2024, in prep.), as well as to produce maps at different number of subfrequencies within the wide spectral band (Chanial & et al., 2024, in prep.).

However, foreground emission may be more complex than anticipated. Not taking into account these complexities during component separation can lead to a bias on the recovered tensor-to-scalar ratio.

In Regnier et al. (2024) and Manzan et al. (2024), we investigate how the spectral imaging capability of the BI can help in diagnosing the presence of foreground residuals in case of simplied foreground modeling. We assume that line-of-sight frequency decorrelations are present in the dust emission but are not accounted for during component separation and we compare the estimated tensor-to-scalar ratio, r, after a Monte-Carlo analysis based on a parametric component separation, in the case of the next generation of ground-based CMB experiment, CMB-S4 (Abazajian et al., 2022), and of a hypothetical version of the same experiment based on BI, CMB-S4/BI. We find that the constrain on r depends on the number of reconstructed subbands, an evidence of the presence of residuals in the foreground cleaning. This would not be possible to achieve with normal imagers, even when many frequencies are used.

We highlight the potential of BI for CMB polarization experiments that will be challenged by complex foregrounds in their quest for B-modes detection.

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Photospectral synthesis of galaxies in the middle age of the Universe

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Keywords: *galaxies: high-redshift, galaxies: stellar content, galaxies: fundamental parameters*

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Detailed full spectral synthesis studies of the stellar populations in galaxies are usually restricted to the local Universe ($z \leq 0.1$), where data is more abundant. Spectroscopic observations of galaxies at redshift's 0.6–1.0 by the Large Early Galaxy Astrophysics Census (LEGA-C) survey (van der Wel et al., 2016) allow spectral synthesis studies similar to those performed in the Local Universe, but for systems half as old. These spectra are complemented with photometry from a wealth of sources from the COSMOS survey (Scoville et al., 2007). These pan-spectral data allow more reliable stellar populations fits than those based only on optical spectra. Photometric and spectroscopic data are fitted simultaneously with the latest version of the STARLIGHT (Cid Fernandes et al., 2005) code. The photo-spectral fits obtained are excellent. The intrinsic properties (masses, average age and metallicity, extinction, star formation history) derived from these fits allow detailed studies of these objects.

STARLIGHT fits the observed data by combining stellar population models and taking into account kinematics and dust attenuation, creating a synthetic model whose fluxes for each population reflect a non-parametric star formation history. We used 98 base models, assuming constant star formation rate in each time interval, built from 2019 Bruzual and Charlot Models covering 7 metallicities and 14 age bins, from zero to 8.5 Gyr ($z \leq 1$). The VLT spectra are scaled to match the overlapping photometry to ensure consistent fluxes. A typical result from the photospectral synthesis is exemplified in Fig. 1.

The bottom panel in Fig. 1 shows the UVJ diagram for 3558 LEGA-C galaxies, with regions corresponding to Quiescent, Starforming and Redenned–Starforming galaxies indicated. Points are colour-coded by the flux-weighted mean (log) age of the stellar populations derived from our photospectral fits. These results illustrate the potential of this new tool to map galaxy properties across cosmic times.

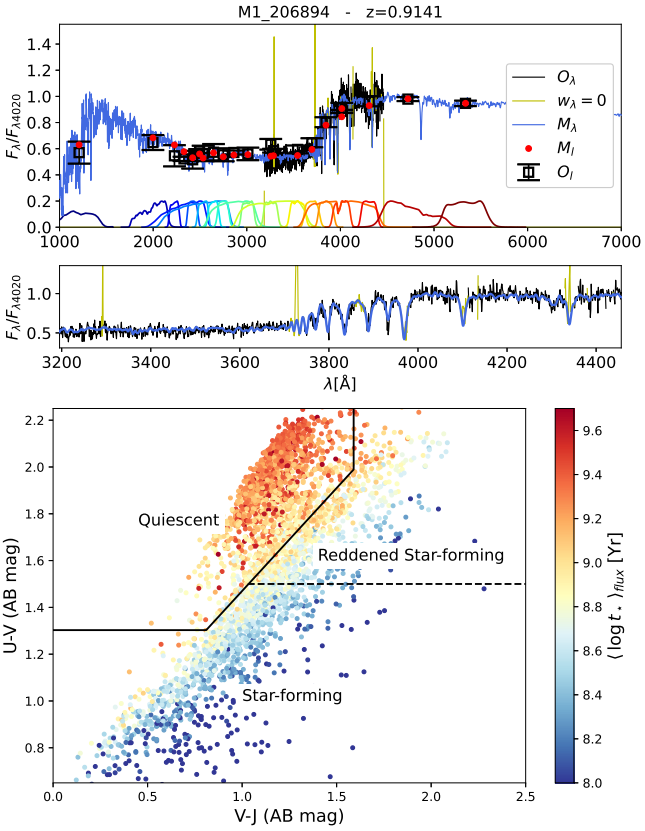

Figure 1. Top: Example photospectral fit of a LEGA-C galaxy. Black and blue lines, black boxes with errorbars and red dots are the observed and synthetic spectra, observed and synthetic photometry, respectively. Transmission curves for the different filters used are also shown. Middle: Zoom on the spectral fit. Bottom: UVJ diagram for LEGA-C galaxies, colour-coded by the mean log stellar age derived from our STARLIGHT fits.

Based on data obtained from the ESO Science Archive Facility with DOI: https://doi.org/10.18727/archive/39

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Accretion disk parameters estimations in the Einstein Cross system Using chromatic microlensing from X-Shooter spectra and multi-Epoch photometry

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Keywords: *cosmology, gravitational lensing: micro, quasars: general*

We present the estimation of the accretion disk temperature profile and size (p and r_s) for the QSO2237+0305 gravitational lens system. These estimates are done by measuring the magnitude differences produced by chromatic microlensing at different wavelengths and by assuming a thin accretion disk model (Shakura & Sunyaev, 1973).

At present, there are nearly 220 gravitational lens systems discovered and confirmed with different techniques. However, only in a fraction of them have chromatic microlensing and, thus, are suitable to estimate their internal structure with this technique.

QSO2237+0305 (the "Einstein Cross" gravitational lens system, Huchra et al. (1985)) has four quasar images that form in the bulge of a spiral galaxy ($z_s = 1.695$, $z_l = 0.039$). These images are susceptible of microlensing by stars. We analyzed spectra from VLT/X-Shooter and compared photometric data from CASTLES[1] database Falco et al. (1999) and Mosquera et al. (2009). The spectra of each quasar image show several prominent emission lines (Ly-α, CIV, CIII], MgII, Hβ and Hα) and continuum emission from the accretion disk. As the narrow line region (NLR) is larger than the accretion disk, is not affected by microlensing (contrary to the continuum). Thus, we used the flux integrated in the narrow emission lines (NELs) as a baseline of no microlensing. We measured the magnitudes difference (MD) as $m_A - m_B = -2.5 \times Log(F_A/F_B)$ between the flux in the NELs (and continuum) for each pair of images. We observed chromatic when continuum MD in the bluest part of the spectra is larger than in the reddest part respect to the NELs MD (Motta et al., 2017). We selected three representative wavelength of the spectra (in λ327 nm; λ516 nm; λ754 nm) to measure the slope of the chromatic microlensing.

[1]CfA-Arizona Space Telescope Lens Survey.

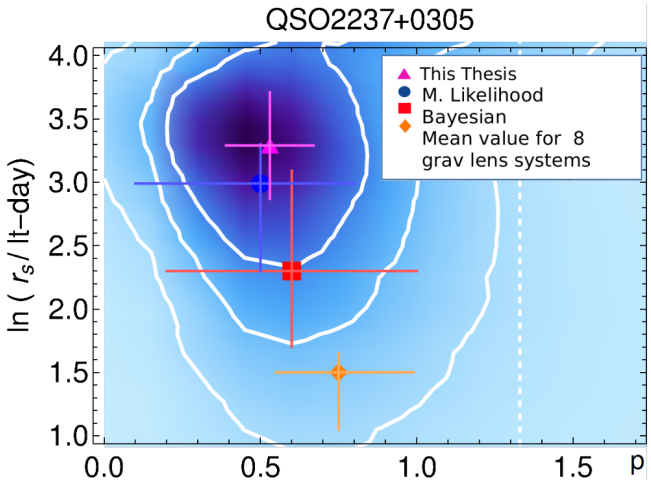

Figure 1. PDFs of the p and r_s parameters. White contours are the confidence level at 0.5σ, 1σ, 1.5σ y 2σ, respectively. White dashed line is the Shakura & Sunyaev disk model, with $p = 4/3$.

We use the inverse polygon mapping method (Mediavilla et al., 2006) to simulate the microlensing magnification using the properties of the matter distribution of the lens galaxy (obtained from the lens model). By convolving our disk model at three different rest-frame wavelength (with λ reference 1026 Å) and varying the accretion disk parameters (p and r_s, with $r_s \propto \lambda^p$) we have estimated the likelihood of reproducing the observed MD. The probability density functions of the accretion disk parameters at 1σ shows a maximum when $r_s = 26.8^{+14.1}_{-9.2} \sqrt{0.3M/M_\odot}$ ld-day and $p = 0.53 \pm 0.14$. Our results are in good agreement with previous research (Jiménez-Vicente et al., 2014).

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The cluster initial mass function of the M82 disk Super Star Clusters

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Keywords: *galaxies: clusters: general, stars: mass function*

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Super Massive Clusters (SSCs) are thought to be the progenitors of Globular Clusters (GCs) due to their similar masses and densities. One way to test such a link is via the Cluster Mass Function (CMF), related to the Cluster Luminosity Function (CLF) via the mass-to-light ratio. We analyze the CMF of SSCs in the M82 disk, exploring the potential initial conditions that reproduce it, known as the Cluster Initial Mass Function (CIMF). M82 is an excellent candidate for this study as it harbors approximately 400 nearly coeval SSCs. Using EMACSS, we perform dynamical simulations on a set of simulated CIMFs and find that a power-law CIMF with an index of 1.8, combined with a power-law galactocentric distribution function, best reproduces the observed CMF. The observed turnover in the CMF is attributed to observational incompleteness rather than intrinsic properties or dynamic effects.

The CIMF can be established from studies of young clusters (age$\sim$ 1—10 Myr). Several studies have reported a power-law CIMF with an index of 2. However, several galaxies display shallower values suggesting that the CIMF index value might not be universal. For instance, M82 has a CIMF index value of 1.8. To delve into this difference, we use the semi-analytical dynamical evolution code (EMACSS, Alexander et al. (2014)) to carry out the dynamical evolution of the CIMF, assuming clusters move in circular orbits under the gravitational potential of M82. We explore two power-law ($\alpha = 2.0$ and $\alpha = 1.8$) and three log-normal functions ($\log \overline{M}$ of 4.23, 4.5 and 5 $M_\odot$) for the CIMFs and populate the clusters in the disk assuming uniform, power-law, and exponential radial distribution functions. We evolve the CIMFs for up to 100 Myr, and apply a mass completeness function (Cuevas-Otahola et al., 2023) derived from the luminosity completeness function in Mayya et al. 2008. We show the observed CMF for the M82 disk SSCs (Mayya et al., 2008) along with the evolved and completeness-corrected CMFs in Fig. 1. The upper left panel illustrates the best agreement with the observed CMF, particularly for the solid and dashed lines

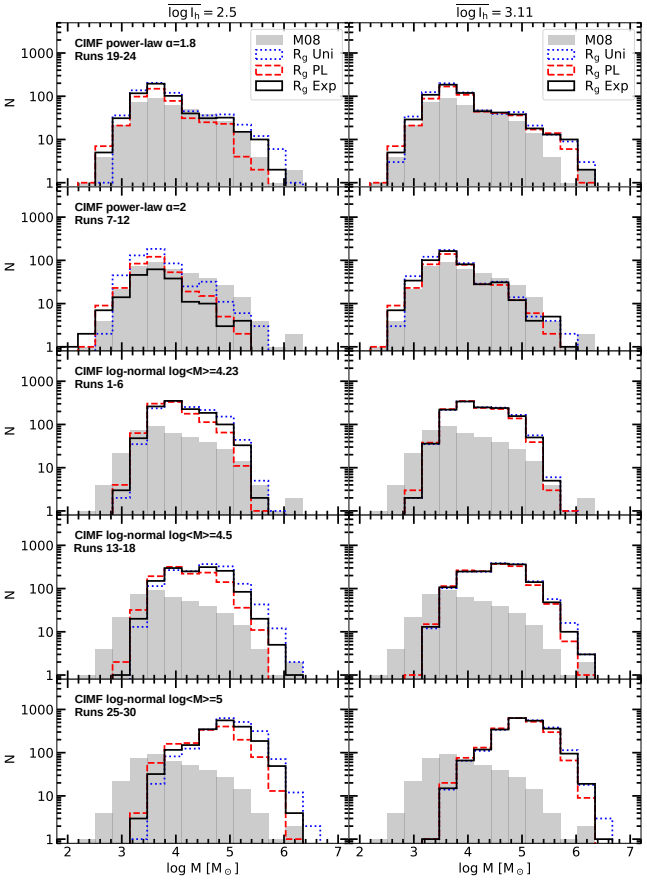

Figure 1. Evolved CIMFs, for lower and higher surface densities (left and right panels respectively) through 100 Myr with EMACSS (see Cuevas-Otahola et al. (2023)).

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(representing exponential and power-law galactocentric radii distributions) with CIMFs having an index of 1.8.

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The S-PLUS Fornax Project (S+FP): Globular clusters in the Fornax Cluster using the S-PLUS data

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Globular Clusters (GCs) are directly correlated to the mass build up of a galaxy. They are related to the halo creation, the formation of the bulge or subsequent encounters. In galaxy clusters, GCs can be also bound to the cluster potential, being stripped from the infalling galaxies. They are therefore vital for studies of cluster environments as well as group pre-processing. We carried out a photometric study of GCs in the Fornax Cluster (FC) using images observed in the 12 photometric bands of S-PLUS corresponding to 106 S-PLUS pointings around NGC 1399. Those pointings cover a sky area of ∼208 sq. deg towards the FC region. Studying the properties of spectroscopically confirmed GCs, we have designed a method to select GC candidates using structural and photometric parameters, as well as SED fitting techniques using the 12-bands.

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The formation of the smallest galaxies

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We establish a new formation scenario for the smallest galaxies in the Universe, the ultra-faint dwarf spheroidal galaxies. In the ΛCDM scenario, those galaxies form first, but their initial stellar distribution is still unknown, as even the most modern cosmological simulations do not have sufficient resolution. We adapt the Dissolving Star Cluster Model scenario and replace the multiple SCs by a single fractal distribution of stars in the centre of the DM halo. This initial fractal distribution is evolving into the luminous component of the dwarfs we see today. If the stars have initially virial equilibrium velocities, the final $r_{1/2}$ of the resulting dwarf galaxy depends only on the scale-length of the DM halo. This behaviour changes if the stars initially have close to zero velocities. We find in our simulations that $r_{1/2}$ is oscillating after many Gyr of evolution. The oscillations are strongest with larger halo scales and larger fractal sizes. The mean size strongly depends on the size of the fractal and no longer on the halo scale-length. The equilibrium models reproduce the size of UMa II using $R_{\rm scale} = 200 - 250$ pc; the 'cold' initial models need $r_{\rm frac} = 250 - 500$ pc.

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Forecasting cosmological constraints from the velocity angular power spectrum of type Ia Supernovae

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The universe's large-scale structure holds significant information about both geometry of spacetime and the growth of cosmic structures. Recent analysis of modern galaxy surveys have demonstrated the effectiveness of combining observables, such as weak lensing and galaxy clustering, in a multi-probe approach as the 3x2pt function to infer cosmology (Prat et al. 2023; Abbott et al. 2022). Complementary information about the growth of structure can be obtained from peculiar velocities, induced by the gravitational attraction of large-scale structures (Quartin et al. 2022). Type Ia supernovae were not commonly used for growth measurements due to the small number of available objects in current surveys. This situation is about to change with future photometric surveys, such as Rubin LSST, which will offer a large and uniform sample of SNIa for use in peculiar velocity studies (Kim & Linder 2019; Howlett et al. 2017). The main goal of this study is to apply the Fisher information methodology to assess the increase in constraining power when combining the angular power spectrum of SNIa peculiar velocities with the standard Rubin LSST observables. We will investigate scenarios with velocities alone, and in combination with galaxy density and gravitational lensing observables (so-called "3x2pt" observables). This is a first step towards future measurements of cosmological parameters using a combination of Type Ia supernova peculiar velocities and 3x2pt cosmological estimators in the context of Rubin LSST.

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Probing black hole formation via collisions in Black Hole Clusters

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The origin of SMBHs in galactic centers at high redshift is still unknown. In recent decades, astronomers have proposed a wide range of models to explain the formation of these objects. Some theoretical explanations include very large seed masses, hyper-Eddington or supra-exponential accretion, the collapse of the first baryon structures, and the formation of SMBHs via BH mergers. In this project, we examine the formation of a massive object in the nuclear star cluster (NSC) core through the fusion of black holes, in a cluster affected by the potential well of gas. We consider the effect of an external gas potential and post-Newtonian corrections in our study. The model is investigated via N-body simulations using the Nbody6++GPU code. We present the results of 100 simulations, where we vary the mass of the gas potential. Since the simulations are computationally expensive when considering the real speed of light, we treat it as a free parameter and determine results assuming different speeds of light, with the aim of extrapolating our results to the physical value. Our findings indicate that the time of core collapse in the presence of a deeper external gas potential tends to decrease in relativistic clusters. For clusters out of the relativistic state, the trend is completely different, tending to increase for higher external potential. On the other hand, the BH seeds that form are set in two ranges: $\approx 10^4 M_\odot$ for clusters in relativistic states, where almost all BH mergers end in the BH seed, and $\approx 10^3 M_\odot$ for clusters out of the relativistic state. In this case only a few percent of mergers end in the BH seeds.

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Slow bars in dwarf galaxies from the Virgo Cluster

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Dwarf barred galaxies are candidates for hosting slowly-rotating bars. They are expected to reside in massive and centrally-concentrated dark matter halos, which should slow down the bar rotation through dynamical friction. When an interaction induces bar formation and when dynamical friction is efficient, the bar should rotate slowly. Despite being predicted within the cold dark matter cosmology, measurements of bar pattern speed, using the Tremaine-Weinberg (1984) method, find that slow bars seem to be rare. We present a photometric and kinematic characterisation of bars hosted by two dwarf galaxies NGC 4483 and NGC 4516 members of the Virgo Cluster. We derive the bar length and strength using the NGVS deep imaging and the circular velocity, bar pattern speed, and bar rotation rate using dedicated spectroscopy from MUSEVLT. By considering the previously studied IC 3167 (Cuomo et al. 2022), we compare the bar properties of the three dwarf galaxies with those of their massive counterparts from literature. Bars in dwarf galaxies are shorter and relatively weaker, and rotate slightly slower with respect to those in massive galaxies, in agreement with theoretical studies and simulations. This could be due to a different bar formation mechanism and/or to the presence of a large dark matter fraction in the centre of dwarf galaxies. We show that it is possible to push the application of the Tremaine-Weinberg method to the galaxy low mass regime, when the targets are carefully selected and dedicated high quality data are available. However, it is necessary to increase the sample of characterised bars in dwarf galaxies to give stronger constraints on their formation and evolution (Cuomo et al. 2024).

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Revealing the effects of environment on Galaxy Bars: The case of the Virgo Cluster

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Bars are hosted in many galactic discs, spanning diverse environments and galaxy luminosities. The environment largely affects the bar formation, with tidal interactions leading to the emergence of these structures within galaxy discs. The bar structural parameters resulting from tidal interactions in high-density galactic environments could differ from those formed through internal disc instabilities in isolated galaxies. To test this scenario, a viable approach is to compare the structural parameters of bars in galaxies situated within distinct environments. We present the comparison between the two key structural parameters of bars, strength and radius, derived using a Fourier analysis on SDSS *r* band images, in galaxies situated within the Virgo cluster spanning a wide range in luminosities and galaxies located in lower density environments. The analysis reveals that the bar radius exhibits a correlation with galaxy luminosity, indicating that larger bars are found in more luminous galaxies. At fixed luminosities, field galaxies display larger bar radii compared to those in the Virgo cluster. However, when the bar radius is scaled by the size of the galaxy, the disparity diminishes. This is because galaxies of similar luminosities tend to be larger in the field compared to the cluster. Consequently, scaled bars in the Virgo cluster and the field exhibit similar sizes. These findings show that the size of galaxies is the parameter influenced by the environment, while the bar radius remains independent of the environment when scaled by the galaxy size. Therefore, internal dynamics and intrinsic characteristics of galaxies play a dominant role in the formation and evolution of bars, regardless of the surrounding environment (Aguerri et al. 2023).

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In the shadows of bright neighbors: The case of CGCG014-074 and NGC 4546

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Early-type dwarf galaxies (ellipticals and lenticulars) represent the numerically dominant population of galaxies in the central regions of rich groups and clusters in the local Universe. As for their origin, several authors postulate that they are the result of the transformation of disk galaxies that fall into these groups and clusters and that this transformation is due to the interaction with the intracluster medium and the other surrounding galaxies. However, the presence of low-luminosity early-type galaxies in low-density environments poses a challenge to this scenario, and the origin of these galaxies in such environments remains unclear.

It is therefore crucial to study these stellar systems in poor groups and the field, focusing on exploring their morphology, dynamics, stellar populations, and observational properties, all of which can help trace their evolutionary history. In this context, we present a comprehensive photometric and spectroscopic analysis of the lenticular dwarf galaxy CGCG014-074, located at a distance of 14 Mpc, using excellent quality data obtained by the Gemini Observatory. Our study entails an exploration of the photometric properties, stellar formation history, and internal kinematics of CGCG014-074 in order to discuss the evolutionary past of the galaxy and the possible genetic link it shares with its neighbour, the massive lenticular galaxy NGC 4546.

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Properties of the spiral patterns of NGC 2619 through morphological analysis

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We performed a morphological study of NGC 2619. This galaxy is located at coordinates 08h 37m 32.706s (RA); +28d 42m 18.70s (DEC) and is classified as isolated (Hernández-Toledo et al. 2010), Seyfert 2 (Toba et al. 2014), SBc(r) in the Hubble system, and AC9 in the Elmegreen system (Buta 2019). Due to the distribution of its spiral structure, this galaxy allows for the investigation of fundamental processes, such as the evolution of the spiral structure, without the direct influence of galactic interactions. For this study we use images from the SDSS project in the *g*-band.

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Tidal stripping and truncation scenario: From dwarf elliptical to Ultra-Compact Galaxy?

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Dwarf ellipticals galaxies (dE) are found at the low luminosity end(>-18 mag) of the elliptical sequence having smaller sizes and lower luminosities than normal elliptical galaxies. Some dE galaxies host a dense central nucleus (dE,N). Further below of the elliptical sequence, at the massive end of the star clusters region, we find massive (>2 $\times 10^6 M_\odot$) and extended objects (r_{eff} between 10 and 100 pc) called ultra compact dwarf galaxies (UCDs). The goal of our study is to investigate if we can transform dE,N galaxies into UCDs, while orbiting a massive galaxy, like the central galaxies of galaxy clusters (tidal stripping and truncation scenario). Is there enough time to strip the dark matter (DM) halo of the dE,N and the stellar envelope to leave just the bare nucleus as the UCD?. On which orbits would we find such UCDs?. In most of our simulations, the dE,N turns into a UCD and the DM halo gets stripped first. The further evolution is governed by the parameters of the stellar envelope and the orbit of the dE,N around the massive galaxy. Massive dE,N either need close peri-center passages or very long evolution times to turn into UCDs.
On eccentric orbits, objects spend most of their orbital period close to apo-center. So even though it is the pericentric passages that do the damage to our objects, the objects need time to lose mass and transform into UCDs further out i.e. closer to their apo-center. Also most UCDs are found close to the apo-center distance today. We see the following order of importance of our starting parameters:
- pericentre distance
- mass of stellar envelope
- size of stellar envelope
- size of DM halo.

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Impact on black hole population due to seed formation in runaway star collisions in nuclear star clusters

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Nuclear Star Clusters (NSCs) are a potential place to form Supermassive Black Holes (SMBHs) in the center of galaxies. In this work, we present an implementation of an NSC model in GALACTICUS, a semi-analytic code designed for simulating galaxy formation and evolution. Our focus is on exploring the role of NSCs during the formation of SMBHs. We assume here that the dominant channel for NSC formation is the transfer of gas from the galactic bulge into a gas reservoir. The gas transfer rate to the center is assumed to be correlated to the global star formation rate in the galaxy, leading to the formation of NSCs through in-situ star formation at the galactic center. Moreover, we introduce a collapse model for NSCs, where they ultimately collapse into a Black Hole (BH) seed upon reaching a critical mass. This critical mass is reached when the age of the NSC exceeds its collisional timescale. By exploring this collapse scenario, we aim to shed light on its potential implications for the population of SMBHs, as well as the relationships between NSCs and galaxies, SMBHs and galaxies, and NSCs and SMBHs. Our investigation delves into how this collapse scenario can impact the overall SMBH population, as well as the intricate connections between NSCs, galaxies, and SMBHs. This research provides insights into the formation and evolution of NSCs and their impact on the galactic and black hole environments. In our results we find SMBHs with masses up to $\sim 10^9\ M_\odot$ at $z = 0$.

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NIR-IFU observations of the Seyfert 2 Galaxy NGC 262

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NGC 262 is a local Seyfert 2 galaxy that hosts a hidden Seyfert 1 nucleus. In this work, we use adaptive optics (AO) assisted, near-infrared (NIR), integral-field unit (IFU) observations of NGC 262 obtained with the Gemini telescope in the J-band to map the distribution and kinematics of the ionized gas in its inner $0.9\,\mathrm{kpc} \times 0.9\,\mathrm{kpc}$ with a spatial resolution of $\approx 55\,\mathrm{pc}$. Recently, Riffel et al. (2023, MNRAS, 521, 1832) used AO assisted NIR–IFU K-band observations of NGC 262 and found that this galaxy presents kinematically disturbed regions (KDR) seen in ionized gas, which they interpreted as being due to nuclear outflows driven by the active galactic nuclei (AGN). Our modelling of the Paβ emission line corroborates these results. In addition, our observations allowed us to map the distribution of the [SIX]λ1.252μm emission line, which has been identified by previous works as a bluewing associated with the [FeII]λ1.257μm emission line and that could not be further characterized due to the lack of spatial resolution.

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Analysis of the expansion of the universe using Large-Scale structures

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The Hubble-Lemaître Law provides a satisfactory description of the universe's dynamics for low red- shifts and reveals insights about its expansion rate. However, at higher redshift values, additional incorporation of the Friedmann equations within the framework of General Relativity is necessary. This project focuses on analyzing large-scale structures of the local universe, specifically at low redshifts, using Hubble-Lemaître diagrams. The goal is to understand the dynamics of universe expansion by studying the Hubble constant independently of specific cosmological models. By utilizing the ALFALFA catalog, the Hubble constant is measured, considering potential systematic effects and using velocity reference frames that minimize peculiar velocity influences. Transformations of frames of reference, e.g. Local Group and CMB frames, and statistical methods were employed to achieve a more accurate determination of the Hubble constant. Within a 1 sigma confidence level, the values for the Hubble constant are equivalent between the two hemispheres. The findings of this work, which contributed to the publication of an article, shed light on the precise measurement of the Hubble constant and its implications.

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The DIVING^{3D} project: A deep look on the central region of Early-Type galaxies

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An active galactic nucleus (AGN) arises when a considerable quantity of matter is accreted onto super-massive black holes (SMBHs). In elliptical and lenticular galaxies from the local Universe, low-luminosity AGNs (LLAGNs), usually with LINER-like spectra, are predominant. In Ricci et al. (2023, MNRAS, 522, 2207), we presented the final results on the nuclear region of all 56 early-type galaxies (ETGs) from the DIVING^{3D} project, which is a statistically complete sample containing all galaxies from the Southern hemisphere brighter than 12.0 mag (B-band) and galactic latitude $|b| < 15^{o}$. All observations were performed with the GMOS-IFU instrument installed at the Gemini South telescope. We detected emission lines in 86±5% of the objects. In 52±7%, the emission was classified as characteristic of LINERs or Seyferts. No emission of the Hβ or the [O III]λ5007 lines was detected in the other 34±6% of the ETGs. Given their low values of the equivalent width of Hα, we classified them as weak emission line objects. No Transition Objects (composite HII/LINER spectra) were detected in the sample. Broad components are seen in the Hα line of 29±6% of the nuclei. In 41 out of 48 galaxies with ionized nebulae, the source of ionization for the LINER spectra and for some of the weak emission line objects is likely due to a LLAGN, although some of the objects require shocks to explain high values of the [O I]λ6300/Hα ratio.

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Exploring the environments and internal dynamics of relics and compact massive ETGs with TNG50

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Relic galaxies are massive, compact, and quiescent objects observed in the local Universe that have not experienced any significant interaction episodes or merger events since $z \approx 2$, remaining relatively unaltered since their formation. These galaxies with "frozen" history can provide important clues about the intrinsic processes related to the formation and evolution of massive Early-Type Galaxies (ETGs). Using the high-resolution cosmological simulation TNG50-1 from the Illustris Project, we investigate the assembly history of a sample of massive, compact, old, and quiescent subhalos split by 10% of satellite accretion fraction. We compare the evolutionary pathways at three cosmic epochs: $z = 2$, $z = 1.5$, and $z = 0$, using the orbital decomposition numerical method to investigate the stellar dynamics of each galactic kinematical component and their environmental correlations. Our results point to a steady pathway across time that is not strongly dependent on the mergers or the environment.

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UV spectral characterization of quasars

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Active Galactic Nuclei (AGN) are defined based on the accreting material towards the supermassive black hole. The nuclear activity is detected at all wavelengths as a product of the different emission regions, resulting in a great diversity of observational features. The Eigenvector 1 (E1) parameter space has allowed us to organize the AGN diversity based on their observational features in the optical to X-ray ranges. In particular, the E1 optical space has been developed as a "Main Sequence" for quasars using optical spectra. However, a more detailed analysis of the UV region is still missing. The main goal of this work is to classify spectroscopically a sample of 1565 SDSS-V quasars with high redshifts ($z > 1.09$) from the information provided by their UV CIII]λ1909/SiIII]λ1892 and AlIIIλ1860/SiIII]λ1892 emission line ratios, to build a diagram that allow us to distinguish the differences between the AGN of the selected sample. With this classification, we divide our diagram to have average spectra to analyze them individually. We also propose this diagram to organize UV quasar spectra by their intrinsic physical characteristics calculated from the average spectra.

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Use of neon lines in the study of the components present in SEDs of Seyfert galaxies

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The emission line of [Ne V], in infrared, has proven to be a relevant indicator of the activity of an AGN due to its high ionization potential. Likewise, the analysis of the ratio [Ne V]/[Ne II], has allowed to distinguish between stellar environments and AGNs. Based on the above, this work sought to verify from a sample of Seyfert galaxies taken from the CDS-SIMBAD database, that the estimates of the AGN fraction (f_{AGN}) coming from a spectral energy distribution (SED) modeling tool (CIGALE), coincide with the Neon line tracers in the infrared. From NED tables, galaxies containing data on the lines [Ne II]12.8μm, [Ne V]14.3μm and [Ne III]15.5μm were filtered from the initial sample. [Ne V]/[Ne II], [Ne V]/[Ne III] and [Ne III]/[Ne II] ratios were compared with the different physical properties estimated from the best SED model of each galaxy. It was found that, if the entire sample of Seyfert galaxies is taken as a single dataset, it shows a moderate positive correlation between the estimated f_{AGN}, and the [Ne V]14.3μm/[Ne II]12.8μm line ratio with a *Pearson Correlation Coefficient (PCC)* of 0.54, and statistically significant ($p-value = 9.74e-8$) But, if the sample is split according to their classification (obtained from SIMBAD) between Seyfert-1 (Sy1) and Seyfert-2 (Sy2), we found that the correlation is strong only in Sy1 galaxies ($PCC = 0.66$, $p - value = 1.66 \times 10^{-6}$), but weak in Sy2 galaxies ($PCC = 0.28$, $p-value = 0.083$). This same pattern occurs by classifying galaxies by their viewing angle (i) to the torus, and the luminosity of the AGN disk (L_{AGN}^{disc}).

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Using WISE cataloged data for morphology, bulge fraction and Black Hole mass estimation

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We present WISE2MBH, an efficient algorithm for estimating parameters of galaxies and their supermassive black holes (SMBH). Using cataloged photometric data from the Wide-field Infrared Survey Explorer (WISE) and employing scaling relations, WISE2MBH estimates the morphological type, bulge fraction, bulge mass and SMBH mass ($M_{\rm BH}$). The algorithm uses WISE color-color criteria to classify between powerful AGN/QSO and regular galaxies, determine the morphological type and bulge fraction using of functional fits developed by us, using WISE data calibrated against morphological classifications from the 2MASS Redshift Survey (2MRS) for the former and a compilation of bulge fractions available in the literature for galaxies with known morphology for the latter. With K-corrections applied, WISE2MBH performs well up to $z \sim 0.5$. Compared to a sample of local galaxies with measurements and high-precision estimates of $M_{\rm BH}$, our algorithm shows optimistic results, with a Spearman score of ~ 0.8 and an scatter of ~ 0.52 dex. Applying WISE2MBH to the Event Horizon and Environs (ETHER) sample with $z < 3$ yields approximately 2.4 million $M_{\rm BH}$ estimates and 650 thousand $M_{\rm BH}$ upper limits; $\sim$ 80% of these lack previous $M_{\rm BH}$ estimates. For the local universe, the black hole mass function (BHMF) obtained from the sample is in good agreement with predictions from multiple works. Our algorithm will be a valuable tool for target selection for the Event Horizon Telescope (EHT). The WISE2MBH algorithm is publicly available on GitHub.

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Comparing the GW170817 source with type Ia Supernova light curves: Do they converge to the same value of H_0?

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The objective of this study is to answer if it is possible to carry out measurements of cosmological distances, complementing type Ia supernovae with the merger of black holes, evaluating if it is possible to refine the measurement of the accelerated expansion of the Universe, through the detection of waves, gravitational waves generated by the merger of black holes by comparing them with the intrinsic luminosity of type Ia supernovae. The methodology used is shown with the results obtained in the previous work, to contrast the simulation results with the result obtained. This work extends the methodology of the previous work, contrasting the virtual results with those obtained in the publication of the work "A gravitational wave standard siren measurement of the Hubble constant", applying a novel approach to measure the Hubble constant by means of the gravitational waves, applying for the first time a revolutionary method proposed 30 years ago by Bernard Schutz using the source GW170817, detected by advanced LIGO and advanced Virgo on August 17, 2017. The analysis of the shape of the gravitational wave by the merger of black holes or neutron stars allows us to estimate the distance, which allows us to compare, according to the environment of the host galaxy, in relation to its environment, the comparison of light curves of supernovae type Ia contrasting the results, in the distance and how much is the result of H_0.

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Star formation efficiency per free-fall time in a galaxy merger

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We present the results of a Mitacs Globalink Research Internship to analyze the star formation efficiency per free-fall time in NGC 3256 using a method published by Utomo et al. (2018). NGC 3256 is a luminous infrared galaxy at redshift 0.00935. This galaxy is the merger of two gas-rich galaxies and the southern nucleus has a jet driven by an active galactic nucleus. In general, low values of star formation efficiency per free-fall time correspond to mostly high values for star formation rate in NGC 3256. We found that there are 5 locations that do not follow that trend. The lowest value corresponds to the location of the jet of the southern nucleus, which seems to be suppressing the star formation in this part of the galaxy. In addition, two of the lowest values of star formation efficiency per free-fall time are located in a tidal arm, where tidal forces could shear the gas producing low values of star formation rate.

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Accretion disk study of the AGN ESO 362-G18 through reverberation mapping

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In this work, we apply the Reverberation Mapping (RM) technique to estimate the geometry and size of the accretion disk of Active Galactic Nuclei (AGN) ESO 362-G18 using X-ray/UV/Optical observations provided by the Swift space telescope. Advanced techniques such as PyCCF, JAVELIN, and PyROA codes were used to quantify the relationship between temporal variability and AGN lagtimes with respect to a reference light curve in the UV band (1928 Å). To obtain lagtime versus wavelength results, we fit a curve that varies certain model parameters and calculate the χ^2 parameter to compare the best fits. These results give us a deeper knowledge of the physical and dynamical properties of the ESO 362-G18 and its active nuclei, providing advances to the field of AGN astrophysics and knowledge about supermassive black holes (SMBHs) and their interactions with the surrounding galaxies.

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Cosmic rays at the epoch of reionization

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One of the most important open problems in Cosmology is that of the reionization of the intergalactic medium (IGM) during the Cosmic Dawn. Radiation produced by the first galaxies would not have been enough to maintain the ionization fraction of the IGM at large scales. Consequently, complementary ionization agents have been proposed, such as the cosmic rays that escape from the same galaxies. In this work, we investigate the ionizing mechanisms allowed by electron-initiated electromagnetic cascades as they propagate across the IGM, emphasizing the contribution of secondary photons, which has not been extensively explored before. We simulated the transport of all the particles comprising the cascades and calculated both the ionization rate and the energy distribution between the particles and the IGM. Our results show that high energy electrons carry energy far away from the source while ionizing the medium in their path, whilst those with kinetic energies lower than a few keV cool completely through collisional ionization within a distance of the order of kiloparsecs, reinforcing the results of previous works and extending their predictions to higher energy electrons and farther distances from the source. In addition, we show for the first time that photoionization by secondary photons produced in high-energy cascades may contribute significantly to the ionization of the IGM. This remarkable result implies a significant ionization rate in the deep IGM that has not been considered before and could provide an efficient mechanism to maintain the ionization fraction at large scales.

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Metal enrichment of galaxies inhabiting halos of different masses in a Λ-CDM cosmology

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The chemical properties of the baryonic components of galaxies encode crucial information about the formation and evolution of the structure in the Universe. In this work, we study the chemical evolution of galaxies since early cosmic times until the present by using state-of-the-art numerical cosmological simulations. We analyze the evolution of nuclei abundances of galaxies inhabiting halos of different masses, considering physical models corresponding to different feedback scenarios. We pay particular attention to the connection between the chemical properties of different baryonic phases in galaxies (e.g. cold gas, hot gas, stellar component) and try to determine the existence of scaling relations between them which can be compared with observational data.

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Investigating the resilience of dwarf spheroidal galaxies within the gravitational potential of the Milky Way

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Satellite galaxies of the Milky Way (MW) are of utmost importance for the construction of the history of formation and evolution of the Galaxy. In particular, many of these satellites are dwarf spheroidal (dSph) galaxies, which appear in a variety of degrees of dynamic destruction. Beyond that, better understanding the dynamics of these objects as they interact with the MW is crucial because their remnant stellar structures, such as stellar streams, allow us to constrain dark matter models. Therefore, the aim of this work is to use numerical simulations to investigate which orbital and structural features make a dSph galaxy more or less resilient to the forces imposed by the gravitational potential of the MW. To achieve this, we carried out simulations of semi-analytical models: N-body systems (Plummer spheres representing dSph) immersed in a realistic analytical potential of our galaxy. We considered both parallel and perpendicular orbits to the disk of the MW in two cases: circular and rosette-shaped orbits, while keeping track of the mass inside the cores of the spheres. We were able to demonstrate that, for all tested orbits, there seems to exist a direct relation between the central density of a Plummer sphere and the time it takes for it to lose a certain percentage of the mass inside its core. For the rosette-shaped orbits, we also found that the pericentric passages are the most intense moments in regards to the loss of mass of the core, although the apocenter is also significant if it's in a sufficiently sharp turn. However, it was also possible to show that the core can retrieve a relevant quantity of mass during the approaches to the pericenter depending on the interplay between the central density and the general size of the orbit.

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Spatially resolved observations of the peculiar galaxy NGC 232: AGN winds and stellar populations

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We use VLT-MUSE data to explore the ionized gas properties and kinematics as well as star formation history, and chemical abundances of the Seyfert 2 galaxy NGC 232. The data cover a field of view of 60×60 arcsec^2 at a spatial resolution of ∼850 pc. We fit the emission-line profiles with two Gaussian components, one associated to the emission of the gas in the disk and the other due to a biconical outflow. The previously reported jet-like optical structure in this galaxy seems to be associated to the emission of the closer wall of bicone. We have found that the stellar population is predominantly older than 2 Gyr. The AGN seems to quench the star formation in the inner 2 kpc. On the other hand, a higher contribution of younger stellar populations is seen surrounding the walls of the bicone, suggesting a both negative and positive feedback scenario. Regarding the chemical abundance, AGN-dominated and SF-dominated regions show similar abundances of oxygen, leading to the conclusion that both phenomena are being fed from a shared cold gas reservoir.

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Measurements of black holes masses using photometry in high redshift quasars

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We aim to determine the validity of the mass-obtaining method by adjusting the spectral energy distribution using only photometric data. We use the code BADFit (Lai et al. 2023) that computes the fit using *kerrbb* and *slimbh* models from XSPEC, depending directly on the photometric points. We measure black hole masses for 30 quasars in a redshift range of $5.8 < z < 6.6$ belonging to the XQR-30 sample, which includes each object's J, H, K photometry bands (D'Odorico et al. 2023). To complement this information the z, y, W1, and W2 NIR bands were searched for VizieR. The code also uses Bayesian inference to detangle the inner degeneracy of the parameters: mass, accretion rate or luminosity, inclination and spin, after XSPEC gives the possible models. Both models give similar results, with an average error of $\log(M/M_{\odot}) = 0.2$. A comparison between our results and ones using Single-Epoch MgII (Mazzucchelli et al. 2023) shows no significant statistical correlation. With values of $\rho = 0.3$ (p = 0.10) and KS = 0.33 (p = 0.07), the correlation between the masses is moderately low and not very significant. We repeated the analysis considering objects at z<6.1, where values of $\rho = 0.37$(p = 0.14) and KS = 0.24(p = 0.75) are obtained, indicating a small improvement in the correlation but a decrease in significance. We conclude that in quasars at z>6, the Gunn-Peterson effect inflates mass estimates, which can explain inconsistencies in the full sample. Using only photometric data, the analysis of problematic quasars suggests correcting some spectroscopic lines to improve SED placement and mass measurements.

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Revealing the orbital histories of strongly perturbed galaxies in the Abell Cluster A496

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We study a sample of disturbed spiral galaxies in the nearby and apparently relaxed cluster A496 ($z = 0.033$). This work is based on a large volume, HI (21cm) survey from the NRAO-VLA, as well as multi-band optical, NIR (CFHT), and FUV (UVIT- Astrosat) imaging. In a previous work, we reported an intriguing HI galaxy distribution with a large fraction of HI rich galaxies within the densest cluster region. In this work we analyze the orbital histories of both, HI-detected and non-detected spirals based on the projected phase-space (PPS) distribution. The study of the galaxy orbits combined with the HI disruptions helps to explore the role played by different physical mechanisms driving the transformation of galaxies observed in this cluster. This strategy allowed distinguishing galaxies under ram-pressure stripping from those affected by tidal interactions.

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Perturbation effects and the evolution of gLSBGs: The case of *Malin 1* - Past interactions with satellite galaxies

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We study the environment of the giant low surface brightness galaxy *Malin 1* analysing the orbital history of its satellite galaxies by exploring possible close encounters in the past. We find orbits with trajectories that can connect the location of the satellite *exo-Malin 1* with an observed stellar stream candidate, which could indicate that *Malin 1* had a satellite interaction ~ 3 Gyr ago.

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Ultra diffuse galaxy formation constraints and possible detection in S-PLUS images

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In this poster we present our ongoing work in the formation scenarios on Ultra Diffuse Galaxies (UDGs) and their Globular Cluster (GC) populations. UDGs are Low Surface Brightness galaxies with abnormally big effective radii for this mass range (> 1.5 [kpc]). To probe their formation histories, we fit Skewed-gaussian functions to the Globular Cluster Luminosity Functions (GCLFs) of the UDGs using a kernel density estimation and retrieving the Skewed-gaussian parameters via the minimization of the negative log-likelihood function between the KDE and the Skewed-gaussian function. Comparing the parameters of turnover magnitude and standard deviation of the GC Skewed-gaussians of dwarf galaxies in Virgo and Fornax two outlier UDGs are identified, namely NGC1052-DF2 and NGC1052-DF4 (from now on DF2 and DF4 respectively). DF2 and DF4, UDGs lacking dark matter, presents abnormally luminous GCs, with a turnonver magnitude $\sim$ 1.5 [mag] higher than the Universal GCLF peak. Another interesting case is DGSAT-I which is an isolated UDG with an overmassive dark matter halo for it's stellar mass and a spatial distribution of GCs more extended than DF2 and DF4. We also present our future work with the SPLUS survey in the context of the S-PLUS Fornax Project (S+FP) to search for UDGs in the 106 fields of S+FP which covers the Fornax Cluster to $\sim 5R_{\rm eff}$; this is motivated by the detection of Low Surface Brightness galaxies in the S-PLUS data using the SExtractor package.

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Exploring the dynamical systems and observational constraints of cosmological models with mimetic gravity

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The Λ-CDM model has been supported by observations of the Cosmic Microwave Background (CMB), Supernovae type Ia (SNIa), the Hubble parameter and Baryonic Acoustic Oscillations (BAO), and yielded cosmological parameters with precisions of the order of one percent (e.g. CMB analysis). Nevertheless, there are still theoretical and observational claims that depart from the Λ-CDM paradigm. This opens the door to explore alternatives such as the modified gravity theories, ($f(R)$). In this poster, we considered the mimetic gravity that provides a geometric description of dark matter. We presented the dynamic description of the isotropic and homogeneous Friedmann-Lemaître-Robertson-Walker cosmological models with positive spatial curvature coming from mimetic gravity theory. The phase space obtained allow us access to solutions that can represent different stages of the cosmic evolution. The dynamics on invariant submanifolds provide good portrait of the system and its respective neighbourhoods. We therefore can obtain properties of the cosmological models that can be compared with the Observational Hubble database from the cosmic chronometers (OHD) and the Pantheon database from Supernova type Ia (PaSNe). We showed a brief discussion on the observational properties of the ΛCDM models and on cosmological models for mimetic fields with exponential potential (EP) and with inverse quartic potential (IQP), with emphasis on the cosmological constraints provided by this study. From the observational analysis, we provided weak constraints on the main parameters of the EP ($\alpha = 18^{+19}_{-28}$) and IQP ($\beta = -369^{+970}_{-470}$) models. We will explore new priors on parameters such $\Omega_{k,0}$, H_0, as well as on the α (EP) or β (IQP). In addition, we will include the CMB data.

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Ionized gas winds from the nucleus of OH megamaser galaxy IRAS 09320+6134

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Ultra luminous infrared galaxies are extremely bright objects in this spectral range, with luminosities larger than 10^{11} $L_{\odot}$. These objects are commonly seen in mergers of galaxies and are propitious environments for the emission of OH megamasers, luminous and powerful extragalactic masers. Many of the OHM galaxies present a composite spectrum, both with characteristics of intense star formation (Starbursts) and with an active galactic nuclei (AGN). IRAS 09320+6134 is part of a project whose general objective is to relate the properties of the OHM emission and the merger stage of its host galaxy with possible AGN and/or SB activities, in order to better understand the nature of the ionization mechanism of galaxies that present this phenomenon. Observations were performed with GMOS-IFU, on Gemini North telescope. We obtained measurements of the gas kinematics by fitting the emission line profiles with two Gaussian curves each, using IFSCube code. The narrow component is tracing gas emission in the galaxy's disk, shows extended emission for all lines in the whole field of view and its velocity fields show a rotating disk, with amplitudes of $\sim$ 200 km/s. The broad component, interpreted as being due to an outflow of ionized gas from the galaxy's nucleus, shows emission mainly in the central 1.5″ for all lines and its velocity fields presents only negative velocities, with amplitudes of $\sim$ −800 km/s. BPT and WHAN diagnostic diagrams indicate ionization due to an AGN for both components. Outflow properties indicate that its kinetic power is about two orders of magnitude less than the values estimated by cosmological simulations for the AGN feedback to be efficient in suppressing star formation.

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Evolution of low mass dwarf disk galaxies

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Dwarf Spheroidal (dSph) Galaxies are the smallest (10^4 − $10^7 M_{\odot}$, $r_{\rm eff}$ $\sim$ 250 pc) galaxies, their dynamics dominated by their large contents of dark matter. Under the Λ-Cold Dark Matter paradigm, larger galaxies were formed as smaller galaxies merged with each other, making dSphs the basic building block of galaxies. The current dSph satellite population of the MW corresponds to the leftovers of the formation process of the MW. As gas falls into the DM halos, angular momentum conservation will imprint a rotation signature on the system. So far, no rotationally supported, isolated dwarf galaxies have been found. This may be due to different reasons: a) These objects may be faint enough to evade our current efforts to find them. b) Additional internal processes destroy the original rotation signature. c) They are born as pressure supported systems in the first place. We aim to investigate this second option. We use the Dissolving Clusters Model to construct an isolated disk galaxy, and study the evolution of its velocity profile for 10 Gyr. Due to the random motions of the stars within their native clusters, the majority of ejected stars will move in the same direction as the cluster was orbiting the halo, but a fraction of them will gain radial, or even retrograde, orbits, increasing the velocity dispersion of stars in the disk. Reducing the mass of the DM halo increases the number of stars moving against the bulk of the disk. Even at low DM halo mass, even below the star formation limit, there is still the signature of rotation, which persist at all times. This means that if disks, or rotationally supported systems, were able to form at these mass ranges, we would be able to see them on isolated regions.

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Exploring the evolution of galaxies: A comparative study using two Semi-Analytic Codes

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In this study, we compare two semi-analytic models of galaxy evolution, SAGE and GALACTICUS. Our aim is to compare their results and understand their agreement or divergence. We use the Millennium run N-body simulation as input, the Millennium run I with SAGE and the mini-Millennium I with GALACTICUS. We employ a minimal set of physical processes to analyze the performance of the models focusing on statistical analyses . We use similar physical parameters. We examine key aspects including black hole population and galaxy properties, seeking to unravel their strengths and weaknesses. We find that the black hole mass distribution tendency is similar in the models but the mass range is different. Also, the normalized frequency has a different scale. This research contributes to the advance of our knowledge in the galaxy evolution providing insights into the complex process involve.

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The formation of faint and Ultra-Faint dwarf spheroidal galaxies: Modeling the formation of Ursa Major II using AMUSE

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Faint and Ultra-Faint dwarf (UFD) spheroidal galaxies represent an extension of the classical Milky Way satellites to lower luminosities and smaller physical sizes. In this project, we perform numerical simulations using the Astrophysical Multipurpose Software Environment (AMUSE) and the N-body code ph4 to study a new formation model for UFDs galaxies: the dissolving star cluster scenario. We use the UFD Ursa Major II (UMa II) as reference galaxy to probe our formation scenario. We consider 4000 stars with virial equilibrium velocities and equal masses ($M_* = 1\ M_\odot$), representing the total luminosity of UMa II. The stars are randomly placed in a fractal distribution inside the central part of a cored DM halo modeled as an analytical Plummer potential, building up the luminous component of the galaxy. We vary the maximum extension of the fractal distribution ($R_{fractal}$ = 100, 125, 150, 175 and 200 pc) as well as the scale-length of the cored DM halo (R_{pl} = 50, 100, 150, 200, 250, 500 and 1000 pc), to explore the influence of both parameters on the final object. We follow the evolution of the stellar distribution for 5 Gyr. Our results of 175 simulations indicate that all our fractal initial stellar distributions evolve into a typical UFD within 2 Gyr of evolution. This saves a lot of CPU-time as we do not need to follow the evolution all the way to 12 Gyr, that is, the age of the UFDs. We find that the size of the resulting UFD galaxy depends mainly on the scale-length of the analytical DM halo and only marginally on the initial size of the fractal. In essence, this implies that by measuring the half-light radius of the UFD we can deduce the scale-length of the DM distribution. On the other hand, measuring the velocity dispersion of our objects within their half-mass radius we obtain values higher than observed in UMa II.

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Quenching of star formation in galaxies up to large clustercentric distances

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It is well known that galaxy properties depend on their environment, with overdense regions having a low fraction of star-forming galaxies ($f_{\rm SF}$). However, it is unclear how galaxy properties such as velocity dispersion (σ), stellar mass (M_*), group halo mass (M_h), AGN activity, etc., collectively influence the $f_{\rm SF}$ along the clustercentric distance ($R/r_{\rm vir}$), where R is the projected distance and $r_{\rm vir}$ is the virial radius. In this context, we use a complete sample of galaxies in the Sloan Digital Sky Survey's Data Release DR18 along with a logistic regression model to account for the nine different galaxy properties across their entire range of values without binning to investigate how the $f_{\rm SF}$ varies with galaxy properties as a function of $R/r_{\rm vir}$ up to 20 virial radii. Also, we explore the effect of two different star formation rate (SFR) measurements in the $f_{\rm SF}$: one using Hα emission line and the other using UV/optical spectral energy distribution (SED). Our results show that, in general, $f_{\rm SF}$ increases with $R/r_{\rm vir}$, with σ and AGN activity playing a more important role in determining how the $f_{\rm SF}$ varies. Furthermore, when various galaxy properties are taken into account, the dependence of $f_{\rm SF}$ on $R/r_{\rm vir}$ is significantly smaller, being important only for non-AGN galaxies and galaxies with σ values between $1.9 < \log_{10}\sigma < 2.1$. Although the trends in the result are maintained, the extent and variations of $f_{\rm SF}$ depend significantly on the different SFR estimation methodologies.

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The mystery of extremely HI Rich galaxies

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The properties of most galaxies in the universe follow scaling relations related to the physics that govern galaxy evolution. For example, there are scaling relations between the stellar mass of late-type galaxies and their neutral hydrogen (HI) content. Based on these scaling relations we can also identify unusual galaxies, such as HI-deficient galaxies with relatively low HI content and HI-excess galaxies with relatively high HI mass compared to their stellar mass. The possible reasons for the later could be either recent gas accretion or an inefficient conversion of the HI to molecular gas. Since recent gas accretion is difficult to prove conclusively, we investigated gas conversion by analysing the molecular gas content of five extremely HI rich galaxies from the HIX galaxy sample. Carbon monoxide (CO) is a good tracer of the molecular gas content of galaxies, so we obtained CO observations of the sample galaxies with the Atacama Large Millimeter Array (ALMA). We obtained resolved CO maps from which we derived the mass and the distribution of the molecular gas in each of the galaxies. We analysed the kinematics of the molecular gas disks and compared it to the HI, stellar and star formation properties of the galaxies. While we find that our sample galaxies have relatively regularly rotating molecular gas disks, their molecular gas fraction is significantly lower than what is expected from scaling relations.

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Unraveling the sagittarius dwarf spheroidal galaxy at low galactic latitudes

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The Sagittarius dwarf spheroidal galaxy (Sgr) is one of the Milky Way's nearest and most massive satellites. It is being disrupted by the tidal interaction with the Milky Way's gravitational potential, leading to a giant tidal stream that covers a large portion of the sky. As seen from Earth, the core of Sgr lies a few degrees below the Galactic plane, behind the Galactic center; meanwhile, the streams are almost perpendicular to the Galactic plane. Since its discovery, Sgr has been extensively studied; however, the regions at low Galactic latitudes still need a proper analysis, which has been prevented due to the high reddening and significant crowding present in this region. The wide-field, high-resolution, near-infrared coverage of the Vista Variables in the Vía Láctea (VVV) survey is a promising alternative for studying Sgr at low Galactic latitudes. Building on previous research leveraging VISTA capabilities for Sgr analysis, we seek to further our understanding of this dwarf galaxy using the improved VVV-X coverage in synergy with the Gaia DR3 survey data.

We present the preliminary results of the decontamination algorithm employed to separate the stars of Sgr from the field. The algorithm consists of a multidimensional mixture model in the parameter space of proper motions, parallax, spatial distribution, and near-infrared PSF photometry in the bands J, H, and K_s. The model's parameters are obtained following the expectation/maximization algorithm. As a result, we could get a sharp classification of objects covering the area at $0° < l < 11°$ and $-4° < b < -14°$. These results provide a step forward in understanding the intricate characteristics of the Sgr at near-infrared wavelengths and give a better map of the structure of the Sgr and its streams at low Galactic latitudes.

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The dynamically active NGC 5098 group: Sloshing and diffuse intragroup light

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Galaxy groups play an important role in galactic evolution, where galaxies may strongly interact with one another and with the intragroup medium. These groups may later fall into clusters, participating in the development and growth of the large-scale structure. In this study, we examine in detail the group dominated by a pair of elliptical galaxies, NGC 5098, which exhibits a sizable substructure to the south. Using deep g and r imaging from CFHT/MegaCam, we detected a significant component of diffuse intragroup light and a low surface brightness star-forming object. By analyzing the velocity distribution of galaxy members, we propose a dynamical scenario for the evolution of this group, taking into account the sloshing phenomenon detected in the X-ray surface brightness observations made with the Chandra space telescope.

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Probing a protocluster candidate at $z \sim 4,5$ in the COSMOS field

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The densest structures of the Universe formed at the knots of the cosmic web at high redshifts and constitute the present-day clusters of galaxies. They are nearly virialized systems, with a high density of gravitationally bound galaxies. The early stages of these structures are called protoclusters and they are the natural laboratories to observe the role of environmental effects on galaxy evolution. In this work we use submillimeter galaxies (SMGs), which are dusty and highly star-forming galaxies, expected to inhabit peaks of matter density at high redsfhift, as targets for protocluster searches. We use combined wide-band and narrow-band optical photometry to identify Ly-alpha emitters (LAEs) around SMGs at $z \sim 4.5$ in the COSMOS field, as a means to identify typical star-forming galaxies tracing the underlying structure that harbors our target SMGs. Our approach picks out line emitters as narrow-band excess objects, which we designate as Ly-alpha candidates. We use additional IMACS spectroscopic data to confirm these candidates as bona fide LAEs and thus protoclusters members, eliminating low-redshfit interlopers. Our preliminary results point to a mild excess in LAE density around SMGs at $z \sim 4.5$ in comparisson to the field. These preliminary results are consistent with SMGs tracing typical moderate-mass structures of the Universe instead of the more massive ones, that grow into Coma-like clusters. SMGs may be thus an as-yet untapped population to understand the build-up of the more modest and typical galaxy groups and clusters.

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PAH Astrochemistry – Spying on the underlying power source in Dust-Rich galaxies

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One of the most challenging aspects of studying the interstellar medium (ISM) of active galaxies is the intense obscuration by dust. This phenomenon raises debates about the power engine of active galaxies: star formation activity, nuclear activity (AGN), or a combination of both. One way to investigate this issue is by inspecting the dust, particularly the Polycyclic Aromatic Hydrocarbons (PAHs). This class of complex molecules, detected by their broad features at mid-infrared, is a tracer of ionizing radiation by young stars, ubiquitous in the universe, and, more recently, has been found even in circumnuclear regions of AGN. In this work, we use low-resolution spectroscopy by IRS/Spitzer to probe the ISM astrochemistry in 600 dust-rich galaxies to explore the relationship between PAH molecular diversity (size, charge, and composition) and the AGN strength. We use a sample of dusty galaxies (0<z<3.7) encompassing different nuclear activity degrees, such as pure starbursts, U/LIRGs, Seyfert galaxies, and quasars. We proceed with a spectral decomposition and a molecular breakdown, using a suite of theoretical spectra from PAH vibrational transitions. We notice PAH infrared emission is well represented by neutral, small (<50 atoms of Carbon), and pure molecules (with no metal, except Carbon). We see stronger AGNs seem to host more neutral PAHs (77% ±15%) than star-forming galaxies (56%±10%), which can be explained by shielding of molecular gas and photochemical processes, such as electronic recombination and PAH dehydrogenation, where the latter may be favored in stronger AGN. These results help us to understand how the dust is affected by the coexisting AGN and star formation bursts that occur in the evolution process of gas-rich galaxies.

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Morphological study of active galaxies

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Three pairs of galaxies were studied in the g and i bands in which, in each pair, the galaxies share the same morphological structure, but one of them has an active nucleus (**AGN**), while the other does not. The images of the galaxies underwent standard processing and then the morphological characteristics were determined by applying the two-dimensional Fourier transform. With this, the aim of the work was to study the influence of galaxy morphology on nuclear activity.

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The environment of LBAs in the S-PLUS

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High-redshift galaxies form more stars per unit of time compared to galaxies in the local universe. However, it remains unclear whether the trigger for this high star formation rate is related to interactions with the environment or star formation in clumps, due to disk instabilities. The main goal of this project is to investigate the environment of high-redshift analogues, such as Lyman Break Analogues (LBAs), to better understand the influence of the local environment on their properties. Subsequently, these results will be compared with galaxies in the distant universe to evaluate the influence of the local environment on the formation of galaxies 10 billion years ago. Our methodology involves a code that analyzes the fields of the galaxies and measures their respective densities using the k-th nearest neighbor method with $k = 4$, $k = 5$ and $k = 10$. The values of the densities are then compared for different ks. This algorithm was applied to all the galaxies in the DR3 S-PLUS. To evaluate the completeness of our sample, a Schechter function was fitted over the luminosity distribution. The densities were then plotted against galaxy properties to test the robustness of our catalog, and the known relations were successfully recovered. The catalog will be available to the public via the S-PLUS database.

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Neighbourhood watch: A survey of Baryonic substructures in the nearby Universe

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The Neighbourhood Watch is a survey to complete a census of all baryonic structures out to at least the virial radius in a sample of galaxy groups within 18 Mpc in the optical filters $u'g'r'i'$ and $H\alpha$ with CTIO/DECam and in the NIR J,K filters with ESO/VIRCAM. The observations reach unprecedented point source depths of 2.5 magnitudes beyond the peak of the globular cluster luminosity function (GCLF) which will detect > 99% of all compact objects, i.e. globular clusters (GCs) and ultra-compact dwarf galaxies (UCDs), and reveal all low-surface brightness baryonic structures down to ∼28mags/arcsec^2. This dataset will allow for the first time: to derive a complete GCLF out to the virial radius for these galaxies, to search for spatial over-densities and unique age/metallicity distribution functions in the GC population, to detect 10-100 new low-surface brightness dwarf galaxies for each target group to test current state-of- the-art cosmological simulations and to measure their luminosity function in different environments, and probe the complex interaction/merger/accretion history of these groups. Given the DECam community pipeline's inability to properly determine the sky levels around large galaxies, a custom data reduction pipeline has been designed for this particular dataset that employs a combination of different image processing techniques (convolution masking, distortion reduction in chip gaps, adaptive sky modal) leading to improved retrieval of low- surface brightness dwarf galaxies in the final stacks. This poster provides an overview of the survey and present analysis of the final stacks in relation to the objectives mentioned above.

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A comparative of two dual AGNs mergers

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The evolution of galaxies and its connection with Active Galactic Nuclei (AGN) feedback on either suppressing or enhancing star formation remains a subject of ongoing discussion. This research investigates the link between the evolution of Super Massive Black Holes (SMBHs) and their host galaxies through merger galaxies, focusing specifically on rare cases of dual AGN. From integral field spectrograph (IFS) observations, we compare two merging galaxies: SDSS J1414-0000 (z=0.0475) in the early stages of collision; and SDSS J1544-0441 (z=0.042) in a more advanced stage, with projected nuclear separations of ∼ 4.9 kpc and ∼ 3.4 kpc respectively. The two objects have AGN signs on both nuclei, based on the data from the Chandra X-ray Survey. Instrument artifacts and telluric emission lines were identified and removed using PCA, and the stellar continuum signal was enhanced through Voronoi binning. In order to derive the stellar continuum we employ STARLIGHT and for fitting the emission line profile of ionized gas we use IFSCUBE. We noticed that the absence of features common to more advanced stages (tidal tails, stellar bridges, stellar halos, complex kinematics) in SDSS J1414, suggests that these galaxies are experiencing their first perigalactic passage. Furthermore, despite being confirmed as a dual AGN through X-ray observations with a column density $N_H < 10^{23}$, the lack of a broad line in one SDSS J1414 nucleus, also suggests its recent activation. In the future, we aim to refine the fit and address uncertainties associated with it, as well as conduct a more detailed comparative analysis of the galaxies SDSS J1414 and SDSS 1544.

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Stellar mass distribution in barred galaxies through Multi-Band decomposition in the Mid-IR

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Bars are elongated central structures composed of gas and stars, frequent in the Local Universe. They are present in $\sim 65\%$ of spirals and strongly transform their host galaxies. We use 3.6 and 4.5 μm imaging for 371 barred galaxies from the Spitzer Survey of Stellar Structure in Galaxies (S^4G, a mid-IR survey of > 2300 nearby, large and bright galaxies). Suffering no dust extinction and being dominated by the emission of low mass stars, the mid-IR is the best tracer of stellar mass in galaxies. We use the S^4G team's GALFIT-based decomposition of the 3.6 μm images to identify different stellar components — bulge, disk, bar and/or nuclear point source. These 2D decompositions result in a final decomposition model for each galaxy with 1-4 components. Knowing the flux contained in each component, we can estimate the stellar mass of these structures. Our main findings up to now are the following: (1) more massive galaxies have higher bar-to-galaxy mass ratios, and (2) galaxies with a bulge component also present bars with a higher relative mass. We also find that bars are less present in lower mass galaxies ($M_\star < 10^9$ $M_\odot$, $\sim 38\%$). This is consistent with bar fraction studies that suggest that lower-mass galaxies are still acquiring and growing their bars. We are currently working to include the 4.5 μm band into our analysis, with GALFIT-M. With our 3.6 and 4.5 μm multi-band decomposition, we will be able to produce more robust stellar mass values for the bars, bringing us one step closer to understand how the stellar mass content in bars relates to other properties of the host galaxy.

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Modeling the chemistry of early Universe

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The chemistry of the early universe consisted mainly of simple atomic species and molecules composed of hydrogen and helium. Therefore, to understand the chemistry of the early Universe it is necessary to know the chemical processes that these species underwent. Also, the interaction with the CMB (Cosmic Microwave Background) is the best test to determine the evolution and abundance of the primordial species. We model the chemistry of the early Universe as a function of redshift using the astrochemistry package KROME. We focus in the $\mathbf{HeH^+}$ molecule because this molecule has a high dipole moment and is formed from the most abundant species, **H** and **He**. Also, its contribution to the optical opacity affects the CMB. In particular, we will explore the impact on the abundance of $\mathbf{HeH^+}$ of new rates for processes such as dissociative recombination and photodissociation. An accurate determination of the chemical composition of the primordial gas is important to understand the formation of the first stars in the universe.

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Mapping the Zoo of Rest-Frame galaxy SEDs using unsupervised machine learning

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Galaxy spectral energy distributions (SEDs) are well known for being a key factor of galaxy studies. When analyzing them, we can understand their properties and evolution. This work aims to look for alternative methods to analyse and visualise galaxy SEDs in a new manner by applying machine learning techniques. We implement unsupervised machine learning methods to order the zoo of synthetic single stellar population (SSP) of galaxy SEDs into a self-organizing map (SOM). The catalogue of synthetic SSP is generated using Flexible Stellar Population Synthesis (FSPS), where the galaxies are sampled at a fixed redshift of $z = 0.496$ with metallicities in range of $[-0.5, 0.2]$ in $\log(Z/Z_\odot)$. To achieve this, we build a compressed representation for each galaxy SED by implementing an autoencoder algorithm, which is used as the input for the SOM. As galaxy SEDs are grouped by similarity, they will be assigned to a particular category (or node), where neighbouring nodes represent similar spectra. Finally, we prove that this implementation is an efficient method to derive physical properties of galaxies, providing insights and techniques that will be useful for photometric redshifts and more generally to build a model of the galaxy population useful for future cosmological galaxy surveys.

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Unveiling intermediate redshift galaxy clusters within the next generation Fornax survey

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The Next Generation Fornax Survey (NGFS) features very deep stacks of images from visible (DECam u, g, i) to infrared (VIRCAM J, Ks) wavelengths with unprecedented photometric calibration standards. In this work, we present the first results of the ongoing effort to study the clusters in this field, going beyond the local universe. So far, our methodology for detecting clusters is comprised in a four-step pipeline: meticulous photometric analysis, photometric redshift calculation using Bayesian Photometric Z (BPZ; Benitez, N. et al 2004), cluster detection using PZWav (Gonzalez, A. 2014), and estimation of galaxy membership probabilities. As to be expected, our preliminary results in the first of seven tiles ($\lesssim$3 sq. deg. per tile) reveal an array of structures including voids and filaments, visualized using Voronoi Tessellations. Due to the gaps in the spectral coverage, between the challenges we face there are photometric redshift degeneracies, and thus, redshift deserts. Despite this, for the first tile we detect 37 clusters with 5-σ confidence (20 being at z>0.9). Binning in redshift space, we present color magnitude diagrams with clear red-sequence/blue-clouds and study the trend for galaxies within and out of clusters. Although the coverage of NGFS is much smaller than other surveys, it reaches higher redshift, potentially opening for empirical conclusions to be drawn in this window to the universe regarding galaxy evolution.

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Abundance of PBHs from optical and X-ray quasar microlensing observations: Constraints on the dark matter fraction

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The quasar microlensing effect allows us to estimate the mass and abundance of any kind of compact object in the lens galaxies, being sensitive to both, baryonic and dark matter (DM) distributions. Recent results of black hole mergers from the gravitational wave experiments LIGO/Virgo, raised again the interest in studying other astrophysical candidates to be part of the elusive DM nature. One of the possible candidates are the hypothetical Primordial Black Holes (PBHs), which have been extensively studied by the community over the last years. In this work, I present the results of comparing optical and X-ray observations of differential microlensing measurements of image pairs for a sample of lensed quasar systems, with computed microlensing magnification maps through a Bayesian analysis to constrain their abundances in the lens galaxies. To do this, we perform simulations of a mixed population of PBHs of different masses and stars (of constant mass $\sim 0.2-0.3 M_{\odot}$) exploring different relative fractions of both objects, plus a smooth matter component. As a result, for the mass range explored in this work, ranging from planetary to intermediate-mass PBHs ($\sim 10^{-3} M_{\odot} - 60 M_{\odot}$), we provide new upper limits for the estimated fraction of the DM in form of PBHs and set the most complete coverage of this area according to other microlensing studies.

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PostNewtonian dark matter halos

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In this contribution, we are interested in enforcing results reported in other works, where the main statement is that the general relativity formalism is not necessary to describe the physics of the halo around spiral galaxies. Then, an inter-median formalism between the classical Newtonian and the relativistic Tolman Oppenheimer Volkoff ones is used to model a halo filled with perfect fluid and equation of state obtained for the universal rotation curves of spiral galaxies. In order to keep the hydrostatic equilibrium the dark matter should have a nonzero pressure to compensate for the gravitational force of the mass contends in the halo. Then a state equation is demanded to accomplish this requirement and completes the set of space-time nonlinear gravitation field equations obtained from general relativity. The fact that the increment of the central pressure is not enough to support the increment of the gravitational attraction produced by the increment of the mass as seen in the mass-radius relation. The mass reaches a maximum, and after that it starts to fall to reach a minimum. Then, the mass increases again to reach a second maximum and decreases again. The curve starts with large radii and small masses and continues to large masses and small radii. The stable configurations are to the right of the maximums and the unstable ones to the left. As is common, in various mass-radio relations, for large values of the central pressure the curves start to entangle. The post-Newtonian model coincides with the relativistic TOV model so to model galactic halos the Newtonian approximation is sufficient and is not necessarily a relativistic formalism, as seen in the mass-radius and mass-pressure curves.

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Probing the formation histories of Nuclear Star Clusters in the Fornax Galaxy Cluster using UVIT

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The correlations between nuclear star clusters (NSCs) and their host galaxy indicate a fundamental connection between the formation of NSCs and their parent galaxy. A recent study by the Next Generation Fornax Survey (NGFS; Ordenes-Briceño et al. 2018) shows the presence of relatively massive nuclei in the faint dwarf at lower galaxy mass regime $\log(M_{\rm gal}/M_{\odot}) < 9.5$, which could be due to recent or ongoing star formation activity that contributes to an earlier build-up of nuclei relative to the rest of the galaxy. The NUV-optical-NIR colour-colour diagram also indicates the presence of young stellar populations (< 2 Gyr). Extending the SED coverage beyond the Balmer break to FUV allows us to determine the age and mass fraction of these young stellar components more accurately by combining data from NGFS. We obtained FUV data of two massive NSCs from the Ultra-Violet Imaging Telescope (UVIT) onboard AstroSat. We detect the most massive one above three sigma of the background fluctuation.

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