S20 Astrophysics and Astroparticles

Astrofísica y Astropartículas

14/07 Thursday afternoon, Aula 1.15

15:30-15:45	Victor J. Sánchez Béjar *Dynamical masses of brown dwarfs and planets*
15:45-16:00	Jun-Yan (Jerry) Zhang *Chemical Components Analysis of Atmospheres of Ultracool Objects using Laboratorial Spectra*
16:00-16:15	Susana Iglesias *Evidence for amino acids in the gas of the IC 348 star cluster in Perseus*
16:15-16:30	Javier Olivares Romero *The dynamical interaction of the Coma Berenices open cluster and Group X*
16:30-16:45	Nicolas Lodieu *Small-ELF: a propotype for the future ExoLife Finder hybrid optical telescope*
16:45-17:00	Pedro Villalba González *The Canadian Galactic Emission Mapper (CGEM): An 8-10 GHz Northen Sky Polarization Survey*
17:00-18:00	**Posters and Coffee**
18:00-18:15	Felipe J. Llanes-Estrada *Galaxy rotation favors prolate dark matter haloes*
18:15-18:30	Oscar del Barco Novillo *Primordial black hole origin for thermal gamma-ray bursts*
18:30-18:45	Marusa Zerjal *Nearby young open clusters and their luminosity functions*
18:45-19:00	Ramón Luna Molina *Structural changes induced by temperature variations in ices of astrophysical interest*
19:00-19:15	Miguel Molero Gonzalez *Measurement of the Positron, Electron and Proton Anisotropy with AMS-02 on the ISS*
19:15-19:30	Hernán Gonzalo Asorey *Astroparticle Simulation in Cloud Infrastructures: Applications to Astroparticle Physics*

Posters: **10** Ramón Luna Molina
Refractive index and density of CO ice

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Dynamical masses of brown dwarfs and planets

V. J. S. Béjar[1,2,*], M. R. Zapatero Osorio[3], R. Rebolo[1,2], N. Lodieu[1,2], E. L. Martín[1,2], B. Gauza[4],
and the GTCAO team

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Substellar objects, unlike stars, do not burn hydrogen in their interiors and are no able to reach the main sequence, where the luminosity and effective temperature remain stable, and therefore, they continuously evolve getting fainter and cooler. Since the properties of substellar objects evolve with time, it is difficult to determine their masses without any knowledge of the age and distance. Brown dwarf and planetary mass companions offer a unique opportunity to determine their physical properties and test theoretical evolutionary models. The combination of radial velocity, astrometric and direct imaging techniques allows us to directly measure the dynamical masses of substellar objects.

For these reasons, our group is involved in the development of the Gran Telescopio de Canarias (GTC) Adaptive Optics and Laser Guide Star system (GTCAO-LGS) and the GRANCAIN instrument. The GTCAO system, which is in the last stages of verification and acceptance tests before going to the telescope, together with the GRANCAIN camera is expected to provide nearly diffraction-limited images (resolution of ~50-70 mas) in the near-infrared.

High-resolution images with current ground-based Adaptive Optics (AO) facilities such as GTCAO-LGS system and GRANCAIN at GTC or the EUCLID satellite will identify hundreds of brown dwarf binaries in young clusters and moving groups with separations of few AU and orbital periods of few years. Future instruments such as FRIDA (with GTCAO-LGS) at the GTC, or HARMONY at the ELT will allow us to monitor their orbital motion (both astrometry and radial velocity) and measure their individual masses. With these observations we will be able to determine the mass-luminosity-age relations of substellar objects independently of evolutionary models.

Chemical Components Analysis of Atmospheres of Ultracool Objects using Laboratory Spectra

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Substellar objects have ultracool atmospheres where molecules significantly contribute to the complexity of the spectra. To help with spectroscopic analysis, we are building a library of optical to near-infrared molecular absorption spectra using gas cells and a spectrometer at our laboratories. We already have room-temperature spectra of water vapor, ammonia, methane, hydrogen cyanide, hydrogen sulfide, and several other carbohydrades and deuterated molecules as well.

Recently we have investigated ammonia-to-methane ratios from a specific window in H-band near-infrared spectra which minimizes contamination from other chemicals in late-T and Y dwarfs, using laboratory gas spectra and tens of object spectra from Near Infrared Spectrograph (NIRSPEC) on the Keck Telescope and the Hubble Space Telescope (HST) [1,2,3]. The results are concordant with the theoretical abundance model and suggest that all the late-T and Y dwarfs considered in this work have ammonia-to-methane ratios consistent with that of Jupiter within the uncertainties, suggesting that they have similar chemical abundances, and the overall trend also shows ammonia-to-methane ratio increases when spectral type goes from T7 to Y2.

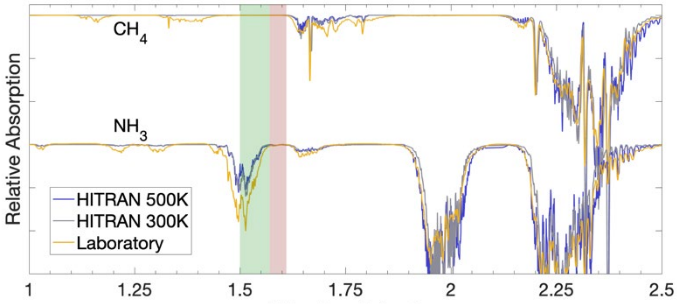

Figure 1. Our laboratory spectrum for ammonia and methane compared to their HITRAN simulated spectra for temperatures of 500 K and 300 K. As an example, a possible wavelength window proposed for NH3-H index is marked with color bands: green for the numerator, red for the denominator.

In the future, we are going to explore more specific spectral window for certain combination of chemicals in our library and we will obtain higher-resolution spectra of objects. Besides, with future deep-sky infrared survey like Euclid, which will be launched into space in 2023. we will have to deal with the spectra of thousands of ultracool objects. Those objects will need to be classified spectroscopically, and our research may provide optimized spectral indices.

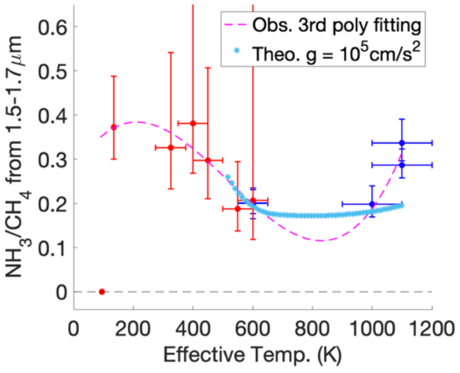

Figure 2. Ammonia-to-methane ratios derived for late-T dwarfs and Y dwarfs with a 95% confidence level from NIRSPEC data (blue) and HST data (red) compared with those of Jupiter and Saturn from IRTF data (red) as a function of Teff. The results are compared with the scaled theoretical ratios of molecular column densities estimated from [4], which are shown in light blue.

[1] Martín, Zhang et al. *Astronomy & Astrophysics* **655**, L3 (2021).
[2] Cushing et al. *Astrophysical Journal* **920**, 20 (2021).
[3] McLean et al. *Astrophysical Journal* **596**, 561 (2003).
[4] Zahnle & Marley, *Astrophysical Journal* **797**, 41 (2014).

Acknowledgements: ELM acknowledges support from the Agencia Estatal de Investigación del Ministerio de Ciencia e Innovación under grant PID2019-109522GB-C53. J.-Y. Zhang acknowledges a summer grant from the Instituto de Astrofisica de Canarias. ELM thanks Mike Cushing for sending the HST infrared spectrum published in [2]. This research has made use of the Simbad database, operated at the centre de Données Astronomiques de Strasbourg, and of NASA's Astrophysics Data System Bibliographic Services.

Evidence for amino acids in the gas of the IC 348 star cluster in Perseus

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Amino acids are building-blocks of proteins, basic constituents of all organisms and essential to life on Earth. They are present in carbonaceous chondrite meteorites and comets, but their origin is still unknown. Formation of amino acids in the interstellar medium is posible via specific gas-phase reactions in dark clouds, however sensitive radiosearches at millimeter wavelengths have not revealed their existence yet. The mid-IR vibrational spectra of amino acids provide an alternative path for their identification. We present Spitzer spectroscopic observations in the star-forming region IC 348 of the Perseus Molecular Cloud showing evidence for mid-IR bands of H2, OH, H2O, CO2, C2H2, C4H2, HC5N, C2H6, C6H2, C6H6, PAHs, fullerenes C60 and C70 and emission lines consistent with the most intense laboratory bands of the three aromatic amino acids, tyrosine, phenylalanine and tryptophan and the aliphatic amino acids isoleucine and glycine. Estimates of column densities give values 10-100 times higher for isoleucine and glycine than for the aromatic amino acids as in some meteorites. The strongest bands of each amino acid are also found in the combined spectrum of >30 interstellar locations in diverse star-forming regions supporting the suggestion that amino acids are widely spread in interstellar space. Future mid-IR searches for proteinogenic amino acids in protostars, protoplanetary disks and in the interstellar medium will be key to establish an exogenous origin of meteoritic amino acids and to understand how the prebiotic conditions for life were set in the early Earth.

The dynamical interaction of the Coma Berenices open cluster and Group X.

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Interacting open cluster pairs are fascinating systems whose numbers continue to increase thanks to Gaia data. These pairs pose exciting questions: Were they formed together? Are their populations mixing? What is the rate of these encounters?

Recent studies show that the Coma Berenices (700 Myr, 86 pc) open cluster and the Group X (400 Myr, 98pc) system, despite their unrelated origin, are interacting and will experience a flyby in 13 to 16 Myr. Given their proximity and extension of Coma Berenice's tidal tails (more than 60pc), this pair offers an excellent opportunity to answer the previous questions.

Using Gaia EDR3 we reassess the membership of these two groups extending the search to half of the northern Galactic hemisphere. Our new lists of members are 50 % larger than those from the literature, cover a wider sky region, and reach the Gaia photometric limit at late-M dwarfs with average recovery and contamination rates better than 99 % and 7 %, respectively. Furthermore, with novel Bayesian inference methods, we infer masses, 3D positions and 3D velocities for all members, including the faint M dwarfs. With this exquisite and complete data set, we reexamine the dynamical state of members in the tails and halos and trace forward their present positions to further constrain the time of the flyby. In addition, we estimate the rate of encounters of open clusters in the solar neighbourhood and analyze the role they play in the mixing and enrichment of stellar populations.

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Small-ELF: a propotype for the future ExoLife Finder hybrid optical telescope

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Technology now exists to enable large optical systems that are capable of resolving and measuring faint sources not accessible with current remote sensing instruments and detectors. The possibility of creating ground-based telescopes at the 50m-scale with sufficient wavefront control to both fully overcome the effects of the atmosphere, but with exquisite coronagraphic capability starting at the telescope entrance pupil, means we may solve some of the most fundamental cross-cutting scientific questions: like, ïs there life outside of the solar system?".

The IAC is part of a consortium with the University of Hawaii and Universities in Lyon to develop the technologies needed for the next generation telescopes aimed at direct imaging of exoplanets around bright stars: the ”ExoLife Finder (ELF)” telescope. We have a detailed design for a 3.5-m diameter prototype, nicknamed Small-ELF, to be built and installed at Teide Observatory by 2025. I will present the technological and scientific challenges of such telescope.

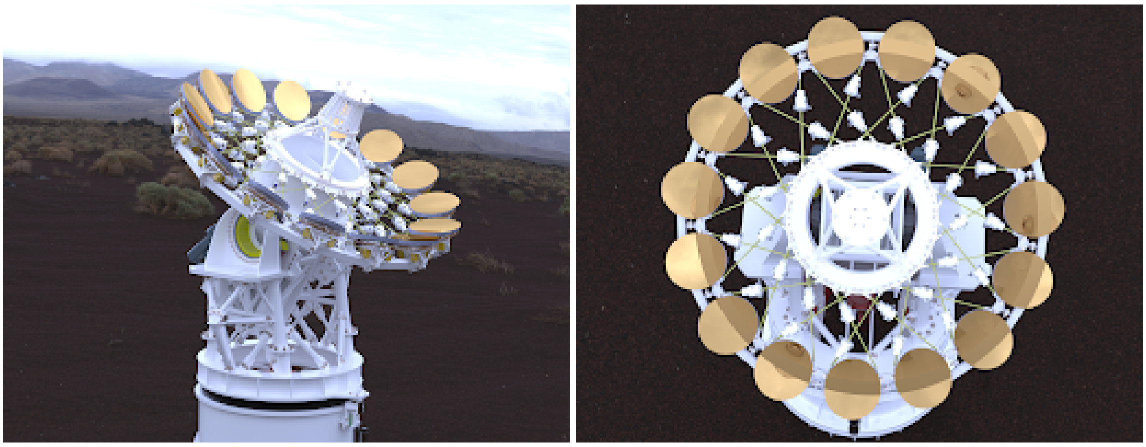

Figure 1. Detailed design of the Small-ELF 3.5-m prototype.

The Canadian Galactic Emission Mapper (CGEM): An 8-10 GHz Northern Sky Polarization Survey

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Inflation is theorized to be a period in the very early universe in which the universe expanded by a factor of at least e^{60} [1]. Since it was first proposed in 1981 [2] it has been confirmed by several observations (see [3], for example), but there is a prediction which has not yet been observed and that would constitute 'smoking-gun' evidence supporting this model, primordial gravitational waves.

Any polarization pattern, and more concretely, the cosmic microwave background (CMB), can be decomposed into two components (E- and B-modes). The ΛCDM model predicts that the CMB polarization is mostly E-mode, with a small B-mode component coming from gravitational lensing. The primordial gravitational waves hypothesized would produce E- and B- modes equally, thus by looking for an excess B-mode signal we would be looking for an imprint of these gravitational waves.

One of the greatest challenges associated with detecting B-modes in the CMB is that CMB B-modes are dominated by polarized Galactic foreground B-modes at all frequencies and angular scales [4]. These foregrounds must therefore be mapped to high precision in order for them to be sufficiently removed from CMB data.

The Canadian Galactic Emission Mapper (CGEM) will be a 4 metre on-axis telescope located at the Dominion Radio Astrophysical Observatory (DRAO) in British Columbia, Canada. It will map the northern sky with ~0.5 degree angular resolution in the band of 8-10 GHz. CGEM will obtain high signal-to-noise Stokes Q and U maps of Galactic synchrotron and spinning dust emission. The main cosmological goal of CGEM is to enable improved foreground models in aid of the CMB B-mode polarization search [5,6]. A secondary goal is to better understand the interstellar medium.

By observing near 10 GHz, CGEM will map these foregrounds at a much higher signal to noise than if they were observed near the CMB window (~100GHz). These maps will then be extrapolated to higher frequency, where they can be used to remove foreground B-modes from CMB data. CGEM will target large angular scales, where the B-mode signal potentially dominates the lensing B-mode signal. In order to aid in the B-mode search, CGEM must have excellent polarization purity. Accordingly, the feed, system geometry, and the shapes of the reflectors are all being carefully optimized to maximize polarization purity.

I will give an overview of CGEM and its science goals. I'll also describe how the experiment is being designed to maximize polarization purity and will outline future plans for the experiment, which we aim to have on sky by the end of 2022.

[1] M. Kamionkowski and E. D. Kovetz, *Annual Review of Astronomy and Astrophysics* **54**, 227 (2016).
[2] A. H. Guth, *Phys. Rev. D* **23**, 347 (1981).
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[5] The PLANCK Collaboration, *Astronomy & Astrophysics* **641**, A10 (2020).
[6] The BICEP/Keck Collaboration, *Phys. Rev. Lett.* **127**, 151301 (2021).

Acknowledgements: We thank the Dominion Radio Astrophysical Observatory, where CGEM will be located, operated by the National Research Council Canada. DRAO is situated on the traditional, ancestral, and unceded territory of the Syilx Okanagan people.

Galaxy rotation favors prolate dark matter haloes

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The flat rotation velocity $v(r) \to$ constant found by Vera Rubin and collaborators and salient in the SPARC galaxy–rotation data base of 175 galaxies [1] falls off Kepler's law in two dimensions. Thus, it is naturally reproduced by elongated dark matter (DM) distributions [2] with the axis of prolateness perpendicular to the galactic plane (see fig. 1), because the force law external to such distribution, $F(r) = \frac{-2G\lambda}{r}$ naturally leads to $v(r) = \sqrt{2G\lambda}$. We report on recent extensive fits [3] to the rotation data.

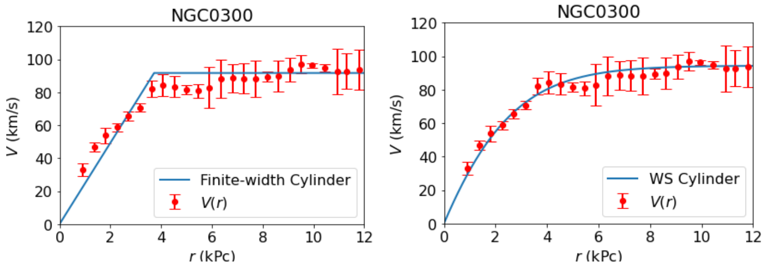

Figura 1: Fits to a typical galactic rotation curve, after discounting the visible matter distribution, with a cylindrical shape. Left: finite width dark matter cylinder with a sharp edge. Right: softened distribution with a Woods-Saxon profile, still cylindrical.

First, contrasting spherical and cylindrical models of DM with different radial profiles, we find that both can work. Spherical DM haloes with $\rho(r) \sim r^{-2}$ (the isothermal exponent) can explain the data; but *essentially any* $\rho(r)$ function with an elongated geometry yields the flattening: for equal dark matter profile except nearly isothermal ones, elongated distributions provide smaller χ^2 than purely spherical ones.

Additionally, we fit ellipsoidal shapes (via models and via a spherical-harmonic expansion) and extract the ratio of the minor to the major semiaxes (figure 2). This is in agreement with cosmological simulations [4], except that we cannot confirm any correlation between ellipticity and galactic mass from the rotation data.

We find that the geometric mean of the individual halo ellipticities is the adequate measure of deformation because $s = c/a \in (0, \infty)$ corresponds to spherical haloes for $s = 1$, so that the common arithmetic average $\langle s \rangle$ is skewed towards oblateness and fails to reveal that a large majority of galaxy curves suggest prolate haloes.

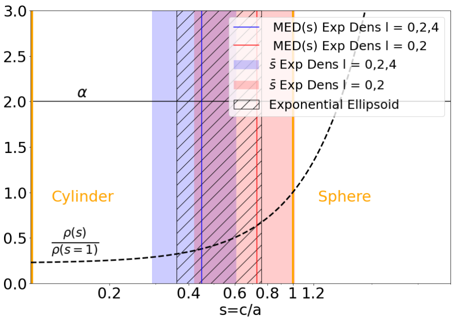

Figura 2: Ratio of the semiaxes of an ellipsoid $s = c/a$ representing a dark matter halo. Our analysis suggests, from empirical rotation curves, that $s < 1$ implying a prolate shape. Shown are the medians and averages with uncertainty with a few terms in a spherical-harmonics expansion, as well as an ellipsoidal model [3] interpolating from pancake to spherical to cylindrical shape.

Several independently coded fitting exercises concur in yielding $s < 1$ for most of the database entries and the oblate exceptions are understood and classified. This likely prolateness (if it would apply to the Milky Way) is of consequence for the estimated dark matter density near Earth, that would be smaller than usually assumed in direct–detection experiments by the factor shown with the dashed line in figure 1.

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[2] F. J. Llanes-Estrada, Universe **7**, 346 (2021).

[3] A. Bariego Quintana, F. J. Llanes-Estrada and O. Manzanilla Carretero, arXiv:2204.06384, under refereeing.

[4] B. Allgood, *et al.* Mon. Not. Roy. Astron. Soc. **367**, 1781-1796 (2006)

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Primordial black hole origin for thermal gamma-ray bursts

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The interaction of an atomic-sized primordial black hole (PBH) with a central black hole (CBH) can be described as an intense gamma-ray emission over a certain period of time [1, 2]. Such gamma-ray bursts (GRBs) are of thermal nature, due to the Hawking radiation emitted by the infalling PBH and detectable by modern observatories like FERMILAT or the projected e-ASTROGAM.

Depending on the specific PBH orbit in the CBH Schwarschild spacetime, our numerical calculations for the PBH Hawking temperature show an initial slight heating followed by a dramatic cooling behaviour. This process is consistent with the temperature evolution of already measured thermal-like gamma-ray bursts (GRBs) [3].

Our results might provide an alternative explanation for such thermal-like GRBs based on primordial black hole origin.

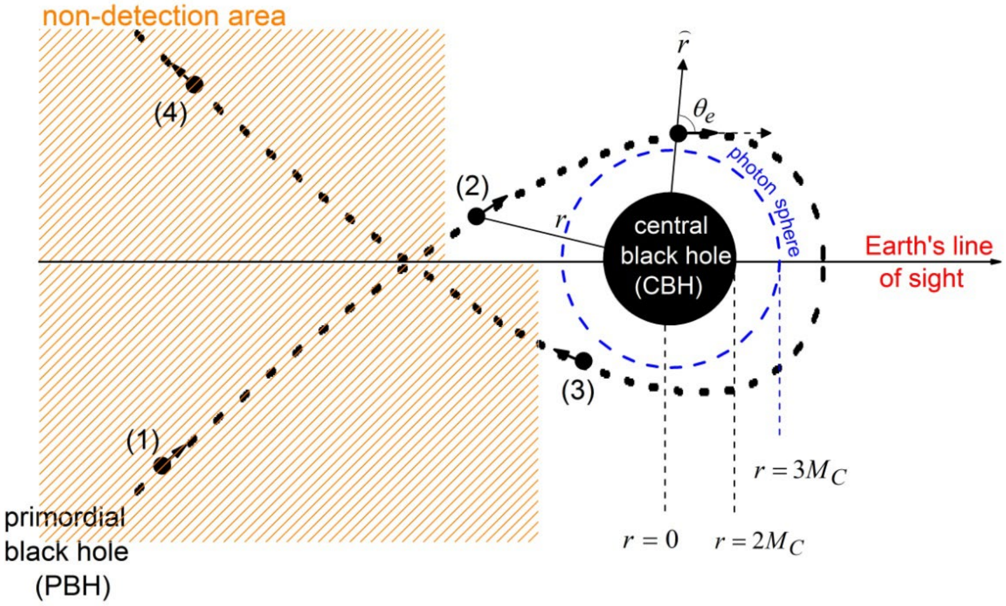

Figure 1. Schematic representation of our binary BH scenario: an atomic-sized PBH approaches a Schwarschild-type CBH describing a typical scattering orbit. The PBH Hawking emission directed toward the Earth might be detected as thermal GRBs.

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[3] F. Ryde, *The Astrophysical Journal* **614**, 827 (2004).

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Nearby young open clusters and their luminosity functions

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Nearby open clusters play a benchmark role in the observations related to the fundamental astrophysical processes, such as formation and evolution of stars and their planets. We used Gaia EDR3 catalogue to place stars in the position-velocity space and re-evaluated memberships of young (<1Gyr) open clusters in the vicinity of the Sun (<500 pc). We re-examined their relative ages revealed from their colour-magnitude diagrams and rotation periods from the TESS data. This enables us to study the evolution of the luminosity function over time and speculate about the gradual evaporation and dispersal of their members into the Galactic disk. With the goal to make these results widely available to the professional and amateur communities, we are building a website with our catalogues of cluster members linked to Aladin and CDS virtual observatory tools. An interactive plots of our members offer an opportunity for users to create their personalised 3D plots and colour-colour diagrams.

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Structural changes induced by temperature variations in ices of astrophysical interest

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Ices of molecules such as H_2O, CO, CO_2, CH_4, CH_3OH… form part of many astrophysical scenarios. Planets, satellites, comets, trans-Neptunian objects, or grains in the dense interstellar medium present evidence of such ices.

Experiments gather data of astrophysical interest for observations, models, simulations… The results we will present study the structural changes (different amorphous structures, crystallization, and diffusion) of these molecules that suffer when a heat source varies their temperatures.

The experiments consist of depositing pure ices or ice mixtures, warming up the sample, and following possible structural variations by mass spectroscopy and laser interferometry. Double laser interferometry and a quartz crystal microbalance let us study the initial structure of such ices or mixtures.

The presentation also will explore the consequences of such structural changes in different astrophysical contexts to show the potentiality of those results.

Acknowledgements: Funds have been provided for this research by the Spanish MINECO, Project PID2020-118974GB-C22.

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Measurement of the Positron, Electron and Proton Anisotropy with AMS-02 on the ISS

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The Alpha Magnetic Spectrometer (AMS-02) is a multipurpose particle physics detector that was installed onboard the International Space Station (ISS) in May 2011 to carry out a long-term mission of fundamental physics research in space. AMS-02 has operated continuously for more than 10 years and has collected more than 2×10^{11} events. The experiment plans to continue collecting data until the end of the ISS (currently 2030).

As of today, AMS has provided the most precise measurements of the positron [1], electron [2] and proton [3] fluxes in the GeV-TeV energy range. On the one hand, the positron and electron fluxes show an excess at high energies which cannot be explained with the traditional models. On the other hand, the proton flux progressively hardens at high rigidities challenging the traditional acceleration and propagation mechanisms.

The origin of these features remains unclear, and a plethora of models have been proposed. In the case of positrons, the additional contribution cannot be explained by a pure secondary component and the inclusion of nearby primary sources is necessary, whether of astrophysical (pulsars) or a more exotic (dark matter) origin. Pulsars represent the leading candidate as primary sources of positrons due to their capability to inject pairs of $e\pm$ in the medium. Contributions from Geminga and Monogem are commonly used to explain the observed excess and predict anisotropies of amplitude $10^{-2} - 10^{-3}$ [4-7]. In the case of protons, the spectral features could also be explained with the inclusion of local sources of high energy cosmic rays or the modification of the current propagation models [7-8].

In this context, the study of the arrival directions of the individual particle species, e.g. their anisotropy, may help to understand the origin of the observed features and, in particular, allows to explore the impact that nearby sources may imprint in the fluxes.

The AMS results on the positron, electron and proton anisotropy will be presented along with the discussion of the implications of these measurements.

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Astroparticle Simulation in Cloud Infrastructures: Applications to Astroparticle Physics

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The Latin American Giant Observatory (LAGO) is an extended astroparticle observatory, consisting of a synchronised network of water Cherenkov detectors operating in Latin America and covering a wide range of altitudes above sea level and geomagnetic rigidity cut-offs[1]. LAGO is operated by the LAGO Collaboration, a highly collaborative organization with 100 members from more than 30 Iberoamerican institutions. LAGO research objectives are focused on studying of high-energy astrophysical and space weather and climate phenomena, by indirectly measuring the temporal evolution of the flux of galactic cosmic rays from ground level[2]. The interaction of such cosmic rays with the atmosphere produces a large number of secondary particles via radiative and decay processes. These true cascades of particles, collectively known as Extensive Air Showers, could reach up to 10^{11} particles at the instant of their maximum development. To accomplish these tasks we have developed several computational tools[3]; that take advantage of the increasing computational capabilities available at high-performance computing facilities and in cloud-based computing environments, such as the European Open Scientific Cloud (EOSC)[4]. With these tools, we can calculate the expected particle flux at any place in the World, including real-time atmospheric and geomagnetic effects, reproducing the expected signals in different types of detectors. We can also calculate the impact in the expected flux due to the occurrence of transient astrophysical phenomena, such as those related to Solar Activity[5] or the high energy component of Gamma-Ray Bursts[6]. In this contribution, we will show how this very complex sequence of simulations is helping us to characterize new sites for our Observatory and the design of improved astroparticle detectors for the LAGO detection network.

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Refractive index and density of CO ice

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Carbon monoxide is an important frozen component of the Solar System and the interstellar medium grains in molecular clouds. This work shows the experimental results of its density and refractive index in the interval 13 to 28 K. Double laser interferometry lets us obtain the actual real part of the refractive index in a high vacuum chamber. The direct measurement of the mass deposited on a known area by a quartz crystal microbalance determines the average density of the deposited material. Both parameters reflect the same behavior with the deposition temperature.

Additionally, we relate both parameters by the Lorenz-Lorentz (L-L) relationship. We also discuss the implications of considering the possibility of obtaining a linear fit to better represent the experimental behavior of our results or maintain the L-L without the independent term of its linear fit.

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