



# INSTITUTO DE FISICA DE PARTICULAS Y DEL COSMOS

UNIVERSIDAD COMPLUTENSE DE MADRID



## IPARCOS WORKSHOP Madrid, 16-17 June 2022 Agenda

Thursday, 16 June

Venue: Room M2, Facultad Ciencias Físicas, UCM, Madrid

09:30-10:00 **Welcoming remarks.**  
**Fernando Arqueros.**

### Current activities of the Institute

10:00-10:20 **Stellar astrophysics and exoplanets.**  
**David Montes** (SEEF).

**Abstract:** In this contribution, we summarize the research areas of the IPARCOS group working on stellar astrophysics and exoplanets. The main areas are Cool Stars (FGK); Stellar parameters (Teff, logg), [Fe/H]; Abundances ([X/H], [X/Fe]); Stellar activity (star-spots, chromosphere, transition region, corona, flares, prominences, etc.); Rotation, age, kinematics; Open clusters; Stellar kinematic groups; Nearby stars; Red dwarfs stars (M); and Exoplanets (detection and characterization and exo-atmospheres). In addition, we update our last results resulting from our international collaborations, such as the scientific exploitation of the Gaia astrometric and photometric data; the analysis of the GES (Gaia-ESO Spectroscopic Survey) data; and the search for exoplanets, and spectroscopic analysis of M dwarfs using CARMENES (Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and visible Echelle Spectrographs).

10:20-11:00 **Activities of the High Energy Physics Group.**  
**Juan Abel Barrio** (GAE).

**Abstract:** The High Energy Physics group (GAE) at the IPARCOS-UCM institute started its activity in the 1980s, focusing on Astroparticle Physics, specifically on experimental Gamma Ray Astronomy. The group pioneered the field in Spain by contributing to the construction and operation of the HEGRA experiment at Observatorio Roque de los Muchachos (ORM - La Palma, Spain). GAE also joined the MAGIC observatory in its design phase and is currently participating in its maintenance and scientific exploitation. In addition, the group is heavily involved in designing and constructing the CTA Observatory and the Fermi satellite scientific case. In this talk, I will present the group's most relevant scientific and technical contributions to the field of Astroparticle Physics field.



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11:00-11:30

**Coffee break**

11:30-12:10

***Activities of GUAIX.***

**Jesús Gallego** (GUAIX).

**Abstract:** The GUAIX group (GUAIX=Grupo Ucm de Astrofísica Instrumental y eXtragaláctica) is composed of a total of 24 people, including UCM staff, postdocs, predocs, and a project manager. Its activities are mainly included in two fields: extragalactic astrophysics and astronomical instrumentation. We are part of major observational and modeling efforts in the field of galaxy formation and evolution (CATARSIS, PHANGS, AGORA, J-PAS, HiMAGC, LeMMING). We are part of major instrumental initiatives for astronomy, such as MOSAIC@ELT and TARSIS@CAHA from the ground (both relying on our expertise from leading the development of the MEGARA instrument for the 10.4m Gran Telescopio Canarias) and ARRAKHS@ESA from Space. We also work on dark-skies and light-pollution awareness initiatives and are responsible for the UCM-CAIs LICA unit, where currently, the SCORPIO 8-channel imager and spectrograph for the US-Gemini telescope are being integrated.

12:10-12:50

***Nuclear imaging and proton therapy.***

**Samuel España** (GFN).

**Abstract:** The talk will address several activities of the GFN-IPARCOS group. We will report on a novel approach to in-vivo proton range verification using contrast agents for PET imaging. In this work, several eggs inoculated with tumor cells were infused with 18-W (18O-enriched water) and irradiated with 8-MeV protons. Activation was recorded using a preclinical PET-CT scanner and further evaluated ex-vivo on excised tumors using gamma radiation detectors. 18-W appears as an innocuous contrast agent which produces PET activity entrapped inside the tumor and provides proton activation in the last-mm of the proton path.

We will also discuss the activities of the UCM-IPARCOS group in cooperation with partners at the Faculty of Pharmacy on FLASH radiotherapy. The group is setting up a radiobiology beamline at CMAM and investigating relevant biological endpoints for dose-rate mediated radiation damage in lung cancer cells (A549) and healthy fibroblasts (IRM90). Data will be reported with proton and photon radiotherapy, including clonogenic assays.

Activities on multimodal radiomics, the extraction of multiple, otherwise invisible features from medical images to provide additional information to predict the biology and underlying behavior of tumors will also be addressed, discussing the analysis of multimodal images (e.g., PET/CT, PET/MRI, PET/CT/Ultrasound) for this purpose.



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12:50-13:10 ***Effective field theories and hadronic structures.***

**Ignazio Scimemi** (TEFM).

**Abstract:** Effective field theories are a powerful tool for analyzing QCD and New Physics effects. I will illustrate the progress of our group in understanding hadronic structures in multiple dimensions, spectroscopy and final state interactions, and physics searches beyond the Standard Model.

13:10-13:30 ***Theoretical gravity and cosmology.***

**José A. Ruiz Cembranos** (TEFM)

**Abstract:** In this contribution, we aim to briefly summarize the recent activity of the IPARCOS members on theoretical cosmology, gravity, and related areas: dark matter, dark energy, gravitational waves, alternative theories of gravity, quantum gravity, string theory,

13:30-15:00 **Lunch break.**

## **IPARCOS Strategic program**

15:00-15:30 ***Strategic program and “high impact” activities.***

**Armando Gil de Paz**

**Abstract:** IPARCOS (still as UPARCOS unit) answered the 2021 call for proposals for new “Units of Excellence María de Maeztu.” During the (admittedly short) phase of preparation of this proposal, a number of key strategic topics were identified. These topics, three scientific and two technological, were those where the combined strength of the IPARCOS could (ioho) be best highlighted, so the need for additional resources for achieving new ambitious collective goals would also be best justified. Besides, in case the evaluation panel considers that the proposal is not yet ready to be fully funded but still worth pursuing, a subset of “high impact activities” was included in the proposal. In this talk, I will discuss the structure of the 2021 MdM proposal along with possible new/alternative paths to prepare a new 2022 proposal, should this one not be awarded.



**SSGI Session: Dark Matter and Dark Energy**

15:30-15:50 ***Indirect dark matter searches with gamma rays.***

**Daniel Nieto**

**Abstract:** The annihilation or decay of dark matter particles with masses beyond a few tens of GeV may produce signatures in the gamma-ray band. Those signatures could be detected by telescopes sensitive to that radiation when observing regions where large dark-matter densities are present. The High Energy Group at UCM (Grupo de Altas Energías) has been designing, building, and operating gamma-ray telescopes for decades. Throughout these years and until the present several works focusing on indirect dark matter detection have been carried out. In this talk, we will summarize past works, the latest results, and what the future may bring regarding this active line of research.

15:50-16:10 ***Identifying the main drivers in the evolution of galaxies.***

**Maritza A. Lara-López**

**Abstract:** The star formation process lies at the center of a web of processes that drive cosmic evolution. Even though it is fundamental to how galaxies assemble their mass and evolve, it is poorly understood. Hence, throughout my career, I have focused on understanding how galaxies evolve through analyzing their fundamental parameters, such as star formation rate, mass, metallicity, and gas content.

With that aim, I have designed and am leading the Metal-THINGS survey, which is obtaining IFU Spectroscopy of a unique sample of nearby galaxies from The THINGS Survey. One of the main characteristics of the THINGS galaxies is that they have spatially well-resolved data across the entire electromagnetic spectrum, from X-rays to radio. Metal-THINGS will fill the currently missing optical-spectroscopic observational gap for these galaxies by providing thousands of spatially resolved spectra. Combined with the resolved multiwavelength information, this will enable the high-precision studies required to constrain the main drivers in the evolution of galaxies.

16:10-16:30 ***Neutrino nucleus interactions for neutrino oscillations.***

**José Manuel Udías**

**Abstract:** Neutrino properties have been investigated for more than 80 years. It has been firmly established that neutrinos oscillate and hence are massive particles. The oscillation parameters have been measured, but still, one needs to determine the neutrino mass hierarchy, the neutrino-mass absolute scale, and whether the neutrino is a Dirac or a Majorana particle.



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Also, investigation of charge-parity (CP) violation in the leptonic sector of the Standard Model is of fundamental importance for the construction of cosmological models. Today, massive efforts on both theoretical and experimental sides are made to achieve these goals. Inevitably, this ambitious scientific program meets challenges that slow down the process. The underlying problem is that the energy of the incident neutrino, a necessary input for the oscillation analyses, is unknown. The neutrino energy is reconstructed using the available experimental information and theoretical models. What complicates the reconstruction of the neutrino energy, and brings theoretical nuclear physics to the stage, is the fact that all present and future generations of neutrino-oscillation experiments use complex nuclei as target/detector material. We will present an overview of some theoretical approaches employed for modeling the main reaction mechanisms involved in the neutrino-nucleus interaction and analyzing the nuclear physics incorporated in the event generators used to design the experiments and analyze the data.

16:30-17:00 **Coffee Break**

## **SSG2 Session: Gravitational-waves and multi-messenger astronomy**

17:00-17:20 ***Light ring images of thin accretion disk in regular compact objects.***

**Mercè Guerrero**

**Abstract:** We discuss the importance of multi-ring images in the optical appearance of two different spherically symmetric solutions when illuminated by an optically and geometrically thin accretion disk. On the one hand, we shall consider some spherically symmetric black hole and wormhole geometries characterized by the presence of a second critical curve via a uni-parametric family of extensions of the Schwarzschild metric. We will show the presence of additional light rings in the intermediate region between the two critical curves. On the other hand, a sub-case of an analytically tractable extension of the Kerr solution, with both a critical curve and an infinite potential barrier at the object's center for null geodesics. Our results point out the existence of multi-ring images with a non-negligible luminosity in shadow observations.



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17:20 -17:40 ***Galaxy evolution and cosmology using gamma rays observed with Fermi-LAT.***

**Alberto Domínguez**

**Abstract:** The light emitted by all galaxies across the history of the Universe is encoded in the intensity of the extragalactic background light (EBL), the diffuse cosmic radiation field at ultraviolet, optical, and infrared wavelengths. The EBL is a source of opacity for very high-energy gamma rays via pair production, leaving a characteristic attenuation imprint in the spectra of distant gamma-ray sources. In this seminar, I will report on new measurements of the EBL using gamma-ray data from the Large Area Telescope on board the Fermi Gamma-ray Space Telescope and ground-based Imaging Atmospheric Cherenkov Telescopes. These unprecedented measurements have allowed us to derive the cosmic star-formation history, the number density of faint galaxies during the re-ionization epoch, and the Universe's expansion rate and matter content. These results demonstrate that gamma-ray astrophysics has matured to the point of providing competitive measurements of cosmic properties previously restricted to techniques used by more traditional astronomy.

## **SSG3 Session: From high precision hadronic observables to new physics**

17:40-18:00 ***Atomic spectroscopy as dark sectors probe.***

**Clara Peset**

**Abstract:** The past two decades have been characterized by extraordinary accomplishments in the control of matter and light. This has opened up new avenues for atomic, molecular, and optical physics, including novel physics tests beyond the Standard Model. The combined use of effective field theories (EFT), precision computations, and highly accurate experimental data makes spectroscopy a competent and reliable testing ground for dark sectors in the keV-MeV range. We present the EFT framework to carry out such a study and propose phenomenological applications: purely leptonic systems such as positronium and muonium and semileptonic systems, where the newly attained proton radius has pushed the theoretical precision of hydrogen and muonic hydrogen spectroscopy.



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18:00-18:20 ***Dispersion relations and QCD spectra.***

**Jacobo Ruiz de Elvira**

**Abstract:** In this talk, I will review how the combination of general principles of analyticity, unitarity, and crossing symmetry, expressed in terms of the so-called dispersion relations, with modern high-precision experimental or lattice data allows one to obtain a phenomenological description of several hadronic processes with unprecedented rigor and accuracy. I will pay special attention to a novel dispersive approach that allows one to analyze isospin-breaking corrections of hadronic observables. For example, I will focus on the pion-vector form factor, a crucial ingredient for the hadronic vacuum polarization contribution to the  $g-2$ .

18:20-18:40 ***Hadron structures through high energy physics in multiple dimensions.***

**Alexey Vladimirov**

**Abstract:** Vector boson production at LHC and semi-inclusive DIS provides important information on hadron composition, momenta of quarks and gluons, and spin correlation. Recent factorization theorems allow to classify these effects and include higher order perturbative contributions. I have also developed the public code Artemide which includes all the latest theory developments.

18:40

**End of session**



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**Friday, 17 June**

**Venue: Room M2, Facultad Ciencias Físicas, UCM, Madrid**

## **TSG1 Session: Instrumentation development**

09:30-9:45 ***Nocturnal remote sensing: a bridge between astrophysics and the interdisciplinary world.***

**Alejandro Sánchez de Miguel**

**Abstract:** Unlike during daylight, when the human presence is barely visible from space, this presence is obvious at night. Although the images of the earth at night are some of the most iconic and omnipresent, there is very little research on those images. One of the main problems is the intrinsic differences between light sources during the day and at night. The lack of signal, the kinds of spectral power distributions, and phenomena make the research of nighttime remote sensing much simpler for astrophysicists than for remote sensing specialists. This opens a large variety of opportunities for knowledge transfer. Currently, there are nighttime remote sensing articles that go from the cancer epidemiology, sleep quality, biological and ecological impacts, poverty estimates, GDP estimates, cultural differences, CO2 emission estimations, and a very long etcetera. Currently, nighttime remote sensing is in a very early stage of development but with exponential growth.

09:45 -10:00 ***TARSIS, the new IPARCOS-led instrument for the Calar Alto 3.5m telescope.***

**Armando Gil de Paz**

**Abstract:** The Tetra-ARmed Super-Ifu Spectrograph (TARSIS) is the new instrument for the 3.5m telescope of the Calar Alto Observatory (CAHA 3.5m), the largest optical telescope in mainland Spain. It consists of four spectrographs covering a total Field-of-View (FoV) of 9 sq. arcmin, the largest FoV of any Integral-Field Unit (IFU) spectrograph to date, either built or planned. TARSIS is called to be Calar Alto's workhorse instrument for years and even decades to come after its first light in 2027. Three of the spectrographs provide an unprecedented wavelength coverage between 320-520 nm, while the fourth one provides complimentary coverage between 510-810 nm over a fourth of its FoV. The instrument is led by the IPARCOS-UCM Group GUAIX & IAA-CSIC. It has major participation from the Universities of Sevilla (US), Granada (UGR), and Almería (UAL), INAOE (Mexico), CAB/INTA-CSIC, private company Fractal, and the CAHA Observatory and was selected for upcoming non-competitive design and MAIT phases on May 18<sup>th</sup>, 2022. In this talk, we will summarize the main characteristics of the instrument and its scientific objectives through the





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ambitious CATARSIS 2D-spectroscopic blind survey of galaxy clusters at redshifts  $0.15 < z < 0.23$ , along with potential synergies with other IPARCOS research and technological interests and capabilities.

10:00- 10:15 ***Nuclear instrumentation from spectroscopy to applications.***  
**Pablo Galve**

**Abstract:** Advanced instrumentation is at the core of developments in several fields of interest for IPARCOS. The talk will focus on nuclear instrumentation for different applications. The first is related to developing high-sensitivity detectors and data acquisition systems for nuclear structure measurements. The IPARCOS contribution to HRST-Brainpet, a PET scanner with unprecedented sensitivity and spatial and time resolution, was funded under the "Development of the Human Dynamic Neurochemical Connectome Scanner" approved by the US Institute of Health with a total budget of more than 8 M€. Finally, the  $\gamma$ MRI project will be discussed with the participation of IPARCOS. It aims to develop a clinical molecular imaging device based on the physical principle of anisotropic gamma emission from hyperpolarized metastable xenon. Researchers at IPARCOS play a key role in designing and developing the gamma detection system and image reconstruction.

10:15 – 10:30 ***CTA-GAE.***

**Luis Ángel Tejedor**

**Abstract:** GAE contributes to the Cherenkov Telescope Array with a critical system in the trigger architecture of Large and Medium-sized telescopes. Every camera contains a Trigger Interface Board, implements the stereo trigger scheme, and manages the different signals. The experience with this system has enabled us with capabilities to design, manufacture and test complex electronic systems. This includes analog design, firmware development for FPGAs, software development for microcomputers, optical communications, and network management. Additionally, we are responsible for the timing distribution in LSTs based on the White Rabbit technology from CERN. Nowadays, we are applying for projects to implement machine learning algorithms in FPGAs at European and national levels.



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## TSG2 Session: Extreme computing

10:30-10:45 ***From Science Operations to instrument and survey management: exploring ML/AI techniques.***

**Francisco Montenegro**

**Abstract:** My recent work has been focused on the efficient scientific operation of the APEX sub-mm observatory. First, as operations astronomer, and later leading the efforts of the APEX Sciops team. Key to boosting scientific productivity has been the progressive adoption of a data-driven methodology inside operations, following the maxim "you cannot manage what you cannot measure." A step beyond is the adoption of algorithms to automatize further processes or, for instance, detecting anomalies without much supervision. ML and AI are being explored in many observatories to optimize operations and have been successfully used to exploit huge astronomical databases. As a new member of the UCM-GUAIX group, I plan to explore some of these techniques for instrument configuration optimization (e.g., TARSIS), data analysis, and the management of survey strategies. Last but not least, I plan to explore synergies in other fields in the context of the IPARCOS collaboration.

10:45-11:00 ***Data Harmonization for Robust and Generalizable Artificial Intelligence Models.***

**Joaquín López Herráiz**

**Abstract:** Artificial intelligence (AI) can potentially improve many data analyses in physics. However, to get the large number of cases required to train the AI tools, acquisitions from multiple sites obtained with a variety of devices and protocols are needed. In this work, I will show the importance of considering the origin and characteristics of the data used for training AI models and how mixing data from multiple sources without proper harmonization methods may introduce significant biases. I will focus on research examples from our group in several medical physics projects (positron range correction, dose estimation in proton therapy treatments). Still, the harmonization methods can be applied to other disciplines.

11:00-11:15 ***Machine learning for very-high-energy gamma-ray astronomy.***

**Daniel Nieto**

**Abstract:** Machine learning has been empowering very-high-energy gamma-ray astronomy for more than a decade now, particularly through enhancing the sensitivity of the various ground-based gamma-ray telescopes that dominate the field. In this talk, we will review the state-of-the-art, elaborate on the several projects currently underway in the High Energy Physics group and discuss our plans for the future.



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11:15-11:30

## ***Faster than light: GPU and DL dose calculations for intrabeam.***

**Paula Ibáñez**

**Abstract:** INTRABEAM is a low-energy x-rays intraoperative radiation therapy (IORT) device mainly used for partial breast irradiation. During an IORT procedure, the final treatment plan is carried out directly in the operating room since some variables, such as the applicator size, may suffer some modifications depending on the final result of the tumor resection. Therefore, a fast and accurate tool to compute dose on the flight is required. In this work, we will focus on two approaches developed in the GFN to calculate dose distributions for the INTRABEAM in real time. One of them is a GPU-based Hybrid MC that calculates dose distributions within seconds with the accuracy of an MC simulation. The other is a Deep Learning (DL) tool trained to instantly calculate 2D and 3D dose distributions in a patient's CT for any INTRABEAM spherical or needle applicator. Either of them has the potential to be used as a dose planning tool in the operating room during an IORT treatment with any INTRABEAM device.

11:30-12:15

## **Coffee Break**

### **New lines and activities. Brainstorming Session**

12:15-12:30

## ***Participation of IPARCOS in the ET project.***

**José Luis Blázquez**

12:30-12:45

## ***Participation of IPARCOS at EuCAPT.***

**José A. Ruiz Cembranos**

12:45-13:00

## ***Participation of IPARCOS at EIC and CERN ptW/ptZ working group.***

**Ignazio Scimemi**

13:00-13:15

## ***IT common resources, computation.***

**Daniel Nieto**

13:15-13:30

## ***Possible strategies for the 2022 MdM-CFP.***

**Armando Gil de Paz & Fernando Arqueros**

13:30

## **End of workshop**