S24 Broadening horizons: interdisciplinarity, general physics and novel research

Ampliando horizontes: interdisciplinariedad, física general e investigación novel

11/07 Monday afternoon, Aula 1.1

15:30-15:45 Welcome and introduction

15:45-16:00 Alejandro Pozas-Kerstjens (Instituto de Ciencias Matemáticas, CSIC-UAM UC3M-UCM / Dpto. de Análisis Matemático, Univ. Complutense)
Physics solutions to machine learning privacy leaks

16:00-16:15 Consuelo Guardiola Salmerón (Centro Nacional de Microelectrónica IMB-CNM, CSIC)
High-resolution beam monitoring with 3D-microdetectors

16:15-16:30 Miguel Ángel Ramos Ruiz (Centro de Microanálisis de Materiales, UAM / Inst. Nicolás Cabrera / IFIMAC)
CMAM: an ion-beam accelerator for multidisciplinary science

16:30-16:45 María de los Ángeles Millán Callado (Dpto. de Física Atómica, Molecular y Nuclear, Univ. de Sevilla / Centro Nacional de Aceleradores, CSIC-US-Junta de Andalucía)
Image and CT capabilities at Centro Nacional de Aceleradores

16:45-17:00 Diego Delgado Bueno (Dpto. de Matemáticas, Universidad de León)
Conserved magnitudes in flatwater canoeing

17:00-17:30 **Posters and Coffee**

18:00-18:15 Ángel Jesús Murcia Gil (Instituto de Física Teórica, UAM-CSIC)
A universal feature of charged entanglement entropy

18:15-18:30 José María Cámara Zapata (Centro de Investigación e Innovación Agroalimentaria y Agroambiental, Univ. Miguel Hernández)
Greenhouse dehumidification through dynamic overhead ventilation

18:30-18:45 Pedro Hernández Cascales (Dpto. De Física, Univ. de Murcia)
Morphology of multi-wavelength selected AGN Host-Galaxies

18:45-19:00 Carlos Yanguas Durán (Dpto. de Automática, Univ. de Alcalá)
Automatic solar burst detection and classification

Posters:

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Physics solutions to machine learning privacy leaks

Alejandro Pozas-Kerstjens[1,2,*], Senaida Hernández-Santana[3], José Ramón Pareja Monturiol[1,2], Marco Castrillón López[4], Giannicola Scarpa[5], Carlos E. González-Guillén[3], and David Pérez-García[1,2]

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For already some years machine learning techniques are being applied in multiple areas of physics in order to attempt to solve difficult problems. The influence goes also in the opposite direction, since tools developed within the realm of physics offer an invaluable perspective on the dynamics of machine learning algorithms. However, despite notable exceptions, the impact of physics in the design of machine learning algorithms is still arguably limited. In this work, we point at physics as a crucial source of inspiration for better machine learning algorithms, especially if one cares about privacy.

First, we identify a new type of privacy leak that involves global properties of the data used for training. Concretely, if the data used for training a machine learning algorithm is imbalanced in some of its features, this imbalance can be detected by only looking at the trained model's parameters, *even if the feature is completely irrelevant for the task* that the algorithm intends to perform. We show that standard neural networks are vulnerable to such privacy leak. Moreover, the state-of-the-art protection mechanisms in machine learning [1] focus on hiding the presence of concrete datapoints in the training dataset. The new vulnerability affects global biases, so it is, a priori, resistant to this protection.

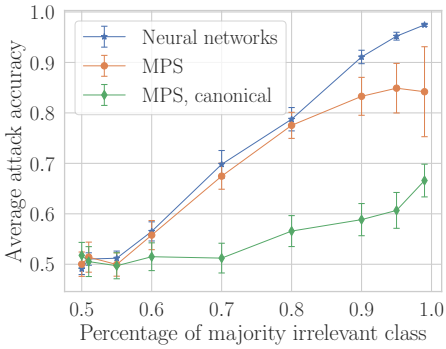

Figure 1. Accuracy of attacks attempting to predict properties of a training dataset consisting of medical records. Importantly, the MPS not expressed in canonical form are vulnerable in a similar way to the neural networks, but the canonical-form MPS achieve a high degree of security.

Second, we make an important connection between privacy and physics. We rigorously prove [2] that robustness to this new vulnerability can be achieved if one can characterize and access the equivalents of a trained model under gauge transformations. Gauge symmetry is a central concept in many areas of physics, ranging from relativity to particle physics. We illustrate the power of gauge symmetry in machine learning by formally proving and showing in practice that matrix product state architectures (MPS) are robust to the vulnerability described (see Figure 1). MPS are inspired by the theory of efficient representation of quantum many-body systems [3], and its use in machine learning is recently showing competitive, and in certain cases better [4], results than standard approaches. Importantly, robustness to the vulnerability discovered is inherent in MPS. This means that, in contrast with traditional solutions for privacy in machine learning [1], in MPS the protection does not impact the performance of the model.

Given the growing expertise in training tensor networks and the recent interest in tensor-based reformulations of popular machine learning architectures, these results imply that, after all, one may not need to make a choice between accuracy in prediction and ensuring the privacy of the information processed when using machine learning on sensitive data. More importantly, they point to physics as a very promising source of inspiration for better machine learning algorithms and architectures.

[1] C. Dwork, F. McSherry, K. Nissim, and A. Smith, *J. Priv. Confid.* **7**, 17 (2017).
[2] A. Pozas-Kerstjens *et al.*, arXiv:2202.12319 (2022).
[3] F. Verstraete, V. Murg, and J. I. Cirac, *Adv. Phys.* **57**, 143 (2008).
[4] J. Wang, C. Roberts, G. Vidal, and S. Leichenauer, arXiv:2006.02516 (2020).

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High-resolution beam monitoring with 3D-microdetectors

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The present work reports on the measurements performed at the Accélérateur Linéaire et Tandem à Orsay (ALTO) facility with the first multi-arrays of microdosimeters with the highest radiation sensitive surface covered so far. The sensors are based on new silicon-based radiation detectors with a novel 3D cylindrical architecture [1]. Each system consists of arrays of independent microdetectors covering 2 mm x 2 mm and 0.4 mm x 12 cm areas, which are arranged in layouts of 11x11 microdetectors and 3x3 multi-arrays, respectively (Fig. 1). We have performed proton irradiations at several energies to compare the performance of the two systems (Fig. 2). The unit-cell of both arrays is a 3D cylindrical diode with a 25 mm diameter and 20 µm thick. Measurements were carried out by irradiating the two detection systems with monoenergetic proton beams from 6 to 20 MeV at clinical-equivalent fluence rates. The microdosimetry quantities were obtained with a spatial resolution of 200 µm and 600 µm for the 11x11 system and for the 3x3 multi-array system, respectively (Fig. 3). Experimental results were compared with Monte Carlo simulations and an overall good agreement was found (Fig. 4). The good performance of both microdetector arrays demonstrates that this architecture can be employed as a multipurpose device for beam monitoring in particle accelerators.

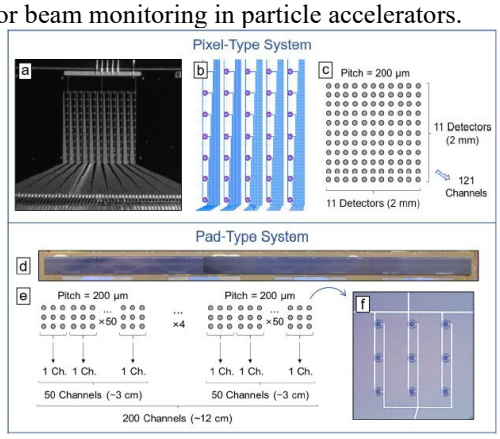

Figure 1. a) Optical image of the 11x11 pixel array. b) Detail of the pixel layout. c) Sketch of the pixel array. d) Photograph of the eight pad-type arrays stacked laterally covering a 12 cm length. e) Sketch of the pad-type array. f) Optical image of one of the 3x3 cells.

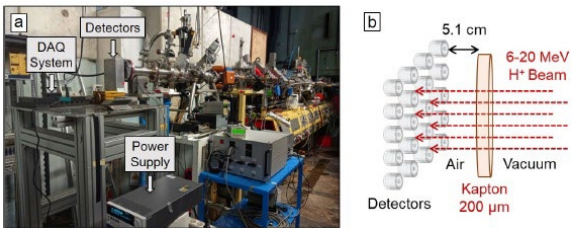

Figure 2. a) Photograph of the experimental setup used for the irradiations at the beamline 410 of ALTO. The distance between the front face of the detectors and the exit window of the beamline was 5.1 cm. b) Sketch of the irradiation configuration.

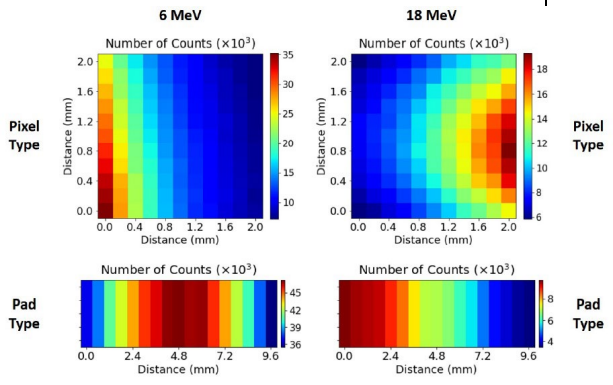

Figure 3. Number of counts measured with 6 and 18 MeV proton beams. Top: pixel-type system. Bottom: 1 cm representative region of the pad-type system (not to scale).

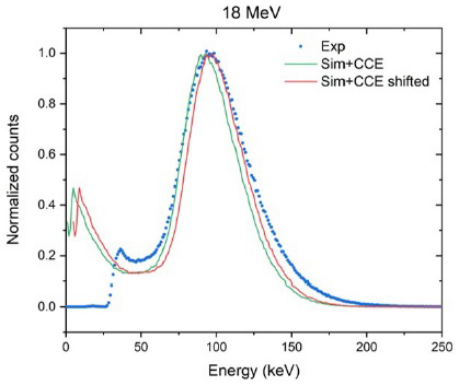

Figure 4. Experimental energy spectra (blue), Monte Carlo simulations of the spectra (green and red) for 18 MeV proton beams.

[1] Guardiola C., et al., *Applied Physics Letters* **107**, 023505 (2015).

CMAM: an ion-beam accelerator for multidisciplinary science

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The Center for Micro-Analysis of Materials (CMAM) [1] at Universidad Autónoma de Madrid (UAM) is an ion beam facility equipped with a 5 MV tandem accelerator and six beam-lines implementing different techniques for analysis and modification of materials at the nanoscale [2]. CMAM operates on the basis of combining a dynamical own scientific program by ascribed scientists with an open user access system, all supported by a team of scientists, technologists and technicians. Recently, the facility has been recognized by the incorporation to the Spanish ICTS (Instalaciones Científico-Técnicas Singulares) map, where it will work in coordination with the CNA (Seville) facility, as a two-node distributed research infrastructure.

The beamlines available at CMAM offer very interesting opportunities to the scientific and industrial communities, making available different ion-beam analysis techniques (such as RBS, ERD, PIXE, PIGE and NRA) and opening the possibility to modify the properties of materials by ion irradiation. Practically any ion species of the periodic table may be accelerated and beam energies may reach 10 MeV for protons, 15 MeV for He and several tens of MeV for mid-mass or heavy ions, reaching the 40-50 MeV range.

Among the many fields in which scientific activities at CMAM may be featured, we have chosen two: (i) irradiation studies for biomedical applications, and (ii) processing of materials for quantum technologies.

(i) Proton beams are an extremely attractive tool for oncological radiotherapy. The beam energies necessary for clinical practice are much higher than those available at CMAM, but 10 MeV protons are ideal for radiobiology experiments in cells culture. During the last few years, CMAM has been increasingly collaborating with different user groups, performing irradiation experiments of different biological samples and under different beam conditions.

(ii) Some of the materials of interest for quantum technologies are very good candidates for processing techniques based on ion beam irradiation. Specifically, we are interested in irradiating diamond crystals, either to produce boron-doped diamond (which can be a superconductor) or nitrogen-vacancy centers (which act as sensitive color centers, useful for magnetometry). We are also exploring the possibility to fabricate amorphous bismuth-antimony films, which could potentially be topological superconductors.

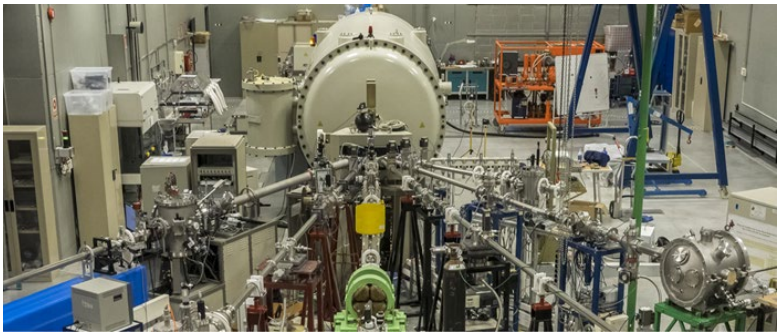

Figure 1. Panoramic view of the CMAM experimental hall.

[1] https://www.cmam.uam.es/
[2] A. Redondo-Cubero et al., *Eur. Phys. J. Plus* **136**, 175 (2021).

Image and CT capabilities at Centro Nacional de Aceleradores

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Centro Nacional de Aceleradores (CNA) is a singular scientific-technical facility located in the Isla de la Cartuja Scientific-Technological Park, Seville. Its installations include a 3MV Tandem accelerator, in which the first accelerator-based neutron source in Spain is installed, a 18/9 MeV Cyclotron accelerator and a ^{60}Co irradiator. In addition to these, CNA also has a clinical PET/CT scanner and portatile X-ray tubes used for studies in X-ray fluorescence.

Since 2018, a number of imaging campaigns have been carried out at the CNA installations, taking advantage of the different irradiation sources, in order to assess their potential for image analysis techniques and its complementarity. In this context, commercially available cameras, scintillators and CCD image sensors have been utilised to perform radiography with X-rays, gamma rays and thermal and fast neutrons.

In this work, the experimental setup optimization is presented, both in image resolution and image quality, as well as exposure time of the final images. The preliminary results of non-destructive testing applied to archaeological object dummies and cultural heritage objects are also shown.

Recently, a commercial rotating turntable, which allows us to perform computed tomography, has also been purchased. This technique has been successfully applied, both with gamma rays and neutrons, to cultural heritage objects and cultural heritage dummies.

Conserved magnitudes in flatwater canoeing

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The field research in flatwater canoeing is developing hardware able of collect synchronized data of acceleration, velocity and applied force versus time, at high sample rates and with good precision. Some months ago we have proposed one dimensional mathematical model for kayak propulsion [1]. This model is supported in a few input constants and in the functional description of the paddler applied force. The so mentioned analysis of field data demonstrates that two conserved magnitudes appear, the average force to stroke frequency ratio,

$$\frac{< f >}{\nu},$$

and the squared asymptotic velocity to stroke frequency ratio.

$$\frac{v_\infty^2}{\nu}$$

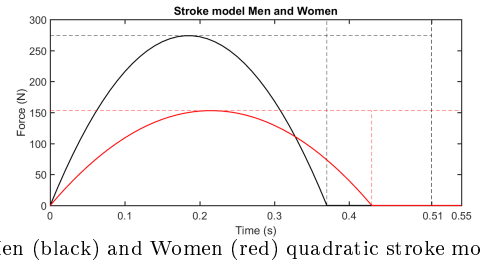
Where ν represents the stroke frequency. From the results of our model, it could be deduced a relation between both magnitudes through the drag coefficient, and to develop one to reach an interesting merit figure to estimate paddler competence and efficiency. The product of the average force integrated over the water phase times the water phase duration, written as:

$$< f >_w \cdot t_w$$

A conserved magnitude as well. Expression that could be reduced, by introducing the integral expression for the average, to reach.

$$\int_0^{t_w} f(t) \cdot dt$$

That in geometrical terms means that average force integrated over the water phase is conserved as stroke frequency increase (and the water phase logically decreased). This merit figure could be a valuable estimator of paddler competence as we will show.



Men (black) and Women (red) quadratic stroke model for maximum frequency. Stroke based on data from Gomes et al [2]

[1] Delgado, D., Ruiz, C., *Applied Sciences* **11**, (2021).
[2] Gomes, B. B., Ramos, N. V., Conceição, F. A., Sanders, R. H., Vaz, M. A., Vilas-Boas, J. P., *Journal of Applied Biomechanics* **31**, (4) (2015).

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A universal feature of charged entanglement entropy

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Rényi entropies, S_n, admit a natural generalization in the presence of global symmetries. These "charged Rényi entropies" are functions of the chemical potential μ conjugate to the charge contained in the entangling region and reduce to the usual notions as $\mu \to 0$. For $n = 1$, this provides a notion of charged entanglement entropy. In this letter we prove that for a general $d(\geq 3)$-dimensional CFT, the leading correction to the uncharged entanglement entropy across a spherical entangling surface is quadratic in the chemical potential, positive definite, and universally controlled (up to fixed d-dependent constants) by the coefficients C_J and a_2. These fully characterize, for a given theory, the current correlators $\langle JJ \rangle$ and $\langle TJJ \rangle$, as well as the energy flux measured at infinity produced by the insertion of the current operator. Our result is motivated by analytic holographic calculations for a special class of higher-curvature gravities coupled to a $(d-2)$-form in general dimensions as well as for free-fields in $d = 4$. A proof for general theories and dimensions follows from previously known universal identities involving the magnetic response of twist operators introduced in `arXiv:1310.4180` and basic thermodynamic relations.

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Greenhouse dehumidification through dynamic overhead ventilation

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High environmental humidity is one of the main problems of greenhouse plant production. When the temperature is low, condensation occurs on the interior surfaces, which modifies the optical properties of the cover material and, consequently, can alter photosynthetic activity. Plant transpiration is also affected, and with it, calcium uptake, hormone distribution, ion pumping, and the opening and closing of stomata, reducing CO2 uptake and crop yield. In addition, the risk of cryptogamic diseases is increased, which is why it is necessary to intensify the treatments with pesticides, with the consequent risk to the health of the consumer. With the purpose of contributing to improve the economic and environmental profitability of greenhouse plant production, the prototype of an environmental humidity control device consisting of an overhead mechanical ventilation system has been used. The results show an important reduction of the specific humidity inside the greenhouse.

Figure 1 shows the evolution of the properties most affected by the operation of the system, the specific humidity (ω, g_{vapor} $kg_{dry\ air}^{-1}$) and the vapor pressure deficit (DPV, kPa). The central black box represents the test interval of February 2, 2022.

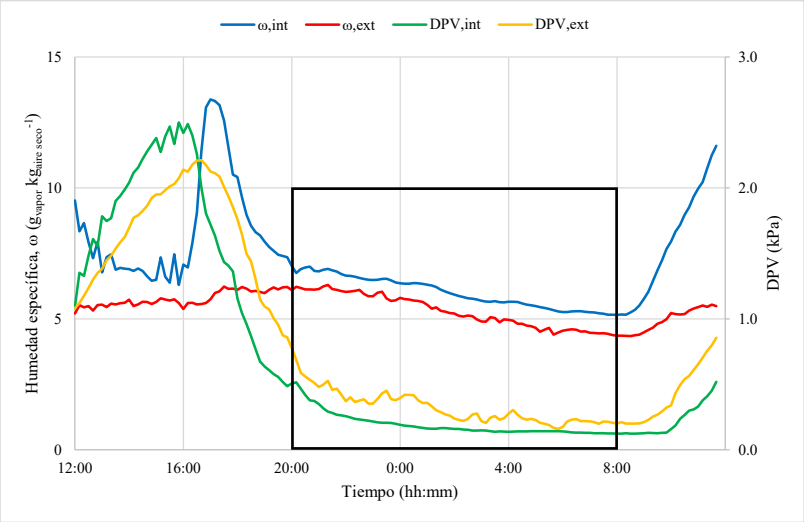

Figure 1. Evolution of specific humidity (g kg^{-1}) and vapor pressure deficit (VPD, kPa) indoors and outdoors on February 2, 2022.

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Morphology of multi-wavelength selected AGN Host-Galaxies

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Over recent years, fundamental relationships between the Active Galactic Nuclei(AGN) and their host galaxies properties have been found, catching the attention of the scientific community on the connection between galaxy evolution and AGN activity. It is now clear that understanding this connection is critical in any attempt to map out the evolutionary pathways of both galaxies and AGN over cosmic time. In this context the study of the galaxy morphology represents one of the most accessible indicators of the galaxy physical structure and can provide valuable clues about star formation and interaction histories. In these studies, high-quality multi-wavelength data are essential to disentangle real co-evolutionary properties from bias due to selection effects and poor statistics.

In this work we study the morphological properties of galaxies hosting AGN compared to those of non active galaxies. In particular we investigate if there is a relationship between the spectral range used in AGN selection and the morphology of the host galaxy.

We identified a sample of 466 AGN in the GOODS-SOUTH CANDELS field, selected with methods based on their emission properties in different wavebands, including:optical variability, X-ray selection, infrared-selection, radio-selection. Different samples of AGN have been compared with each other and with samples of non active galaxies matched in redshift and magnitude.

The results show a notable difference between the non morphological magnitudes of active and non-active galaxies. They equally show that AGN-hosting galaxies tend to have an spheroidal bulge, this effect is mainly present in AGN identified via X-rays. Finally, results also show that non-active galaxies are irregular more frequently. In view of these results, there seems to be a relationship between the presence of an AGN and it's hosting galaxy morphology.

Acknowledgements: I would like to thank my tutors Diego, Francisco y Javier for all their help and patience with me. They have helped me to discover a wonderful field. I would also like to thank my family and friends whose support has been essential not only to complete this work but for my every day life.

Automatic solar burst detection and classification

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Radio bursts from the solar corona provide information to predict space weather hazards. These risks are due to the fact that this phenomenon will cause interference to our radio wave signal and affect the electromagnetic spectrum on earth, which could doom the entire line of communications, including the operation of satellites, the navigation system, the Global Positioning System (GPS), the international power grid and many more.

Since solar radio emissions are in the low frequency range, the detector system consists of a low frequency receiver, in our case the Compact Low Cost Low Frequency Astronomical Instrument for Spectroscopy and Transportable Observatory (CALLISTO).

Based on the morphology and drift rates in the dynamic spectrograms, there are five primary types of radio bursts, type I, type II, type III, type III, type IV and type V as well as other complex bursts that are often observed in the solar corona. Given the importance of this phenomenon and recent technological advances, regular monitoring of radio bursts has increased and large observational data sets have been produced. Therefore, their manual identification and classification is a difficult task implying great human effort for their detection and classification.

In this work, a system for automatic detection and classification of these solar events based on deep neural networks has been devised. Specifically, YOLO in its version four, has been trained with solar events reported since 2020 through manual labeling of solar events, resulting in a model that allows detecting solar events on high-contrast spectrograms generated with typical operations such as background removal. This whole process also has the advantage that it has been developed with open source tools, minimizing the cost of the system.

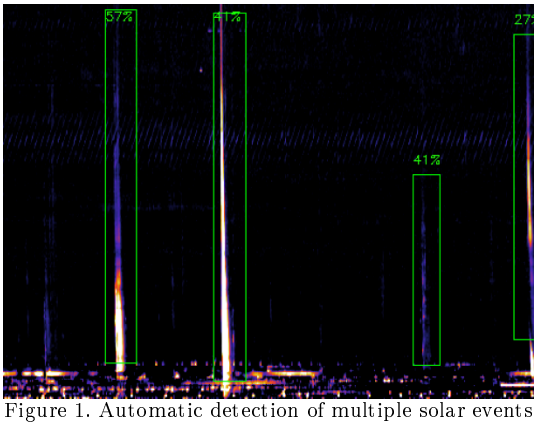

Figure 1. Automatic detection of multiple solar events by YOLO.

This work has been funded by the Junta de Comunidades de Castilla-La Mancha and the European Union (reference: SBPLY/19/180501/000237). With the collaboration of PCTCLM.

Acknowledgements: To the entire CELESTINA project team, especially Manuel Prieto, Javier Bussons and Mario Fernández.

Evaluación del paisaje sonoro de un evento patrimonial en entorno abierto: El Tribunal de las Aguas de Valencia

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La evaluación acústica de entornos interiores es habitual en la aplicación de la acústica virtual. Además, en el estudio de edificios del patrimonio cultural, es una herramienta útil, pero no es tan común en la descripción de ambientes acústicos de eventos en ambientes exteriores. En este trabajose estudia el entorno acústico del Tribunal de las Aguas de Valencia (España). Se analiza desde la perspectiva del paisaje sonoro, caracterizando la fuente sonora y valorando la respuesta subjetiva.

El Tribunal de las Aguas es una antigua institución dedicada a regular y dirimir los conflictos en la gestión de los recursos hídricos de las acequias de Valencia y alrededores. Las sentencias de este tribunal tienen validez jurídica en el territorio valenciano, y constituyen una parte del antiguo Derecho Civil Valenciano que actualmente se está tratando de recuperar en el ámbito jurisprudencial.

La simulación acústica se realizó a partir del modelado del entorno y su ajuste a partir de la medida acústica realizada en el entorno de este evento, que es Patrimonio Inmaterial por UNESCO. Además, se caracterizó en la cámara anecóica de la UPV, una de las principales fuentes sonoras en este evento, que es el alguacil que anuncia a los participantes y se integró en el programa de simulación acústica ODEON (https://github.com/ACUSVIRT/Tribunal). El estudio acústico permitió generar una auralización dinámica a partir de la interpolación de diferentes respuestas impulsivas en un recorrido prefijado. Junto con la simulación acústica y la auralización generada se realizó un modelado visual para la navegación por el entorno y su integración se puede observar en el vídeo https://www.youtube.com/watch?v=JHOxuCvG7n8&t=21s[1]. Además, se realizó la evaluación de la respuesta subjetiva a partir de una encuesta pública basada en el "protocolo sueco de calidad del paisaje sonoro" [2]. Las estadísticas obtenidas (en escala Likert, donde 1 es "muy de acuerdo" y 5 es "muy en desacuerdo") en relación al "protocolo sueco", para las valoraciones del paisaje sonoro percibido por los encuestados muestran que, en general, aunque los oyentes perciben el paisaje sonoro como poco molesto (4,03/1,37), poco caótico (4,19/1,05) y ligeramente emocionante (3,42/1,27) debido a la reverberación percibida, lo interpretan como monótono (2,26/1,25) y poco activo (2,46/1,48), ya que en nuestro caso el evento auralizado sólo presenta una fuente sonora principal (alguacil), pero con reverberación interpolada en cada posición.

(a) (b)

Figura 2. (a) Vista general de la simulación visual del Tribunal de las Aguas. (b) Detalle de la representación de una sesióndel Tribunal de las Aguas.

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Acknowledgements: Esta investigación ha sido parcialmente financiada por el Ministerio de Ciencia, Innovación y Universidades de España, subvención número BIA2016-76957-C3-3-R y por la Universitat de Valencia con la beca UV-INV-AE-1550319.

Computational study of the Hydrogen molecule inside a C_{60} fullerene cage

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Endohedrally confined systems have been a subject of great interest during the recent rears [1, 2]. Besides a few exceptions [3, 4], spherical confinement is considered to study the system, i. e. the system is around the center of the spherical potential.

In this work we address the problem of the Hydrogen molecule under off-centered spherical confinement using two different spherical coordinate systems: a) the one associated to the confining cavity, and b) the one related to the Coulomb charge of the molecule. Off-centered treatment implies that the potential which is not centered needs to be analysed through a partial wave expansion approach.

The purpose of this study is the characterization of the convergence behaviour of the electronic ground state energie of the Hydrogen molecule as a function of the displacement in each one of the aforementioned approximations. A combination of two Woods-Saxon potentials is used to model a C_{60} fullerene cage as the confining environment [5].

Our results show a better performance of the second approach. In Figure 1 we plot the energy of the ground state energy of the H_2 molecule as a function of the position of the centre of the confining cavity, R_{OC}, for different maximum number of partial waves, L, in the expansion. A good accuracy of the energy is obtained from $L = 2$ onwards in the full range of positions of the cavity. The minimum energy coincides with the nuclei close to the structure of the confining cage, therefore the molecule is likely to tend to be in that location.

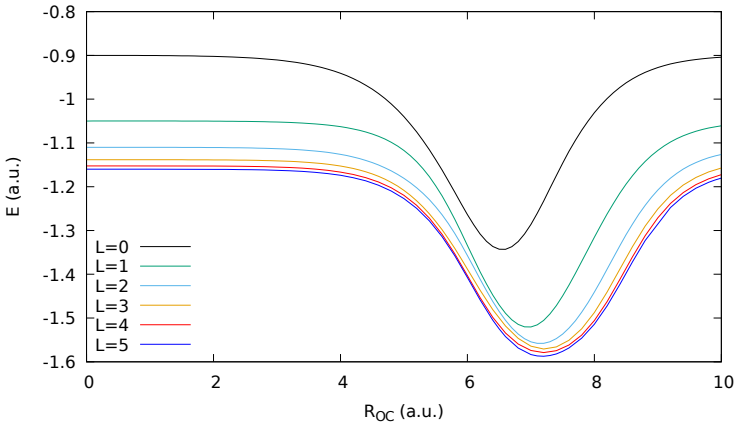

Figure 1. Convergence of the ground state energy of the confined Hydrogen molecule with moving nuclei as a function of the displacement and for different partial waves.

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Acknowledgements: This work was partially supported by the Spanish Ministerio de Ciencia e Innovación under contract PID2020-114807GB-I00, the Junta de Andalucía grant FQM378 and the Universidad de Córdoba under a grant from the program "Plan Propio de Investigación 2019". M.F.M.A. acknowledges partial support by a Ph.D fellowship from the Spanish Ministerio de Universidades under grant FPU16/05950.

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Análisis de la invariancia de escala fractal de series temporales de concentración aérea máxima de polen

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En la naturaleza es común observar estructuras que al dividirlas en partes, éstas tienen una forma similar al total original. A éste fenómeno se le conoce como auto-similitud fractal y se dice que dichas estructuras muestran invariancia de escala. A diferencia de los fractales matemáticos en los que las partes son una copia exacta de la totalidad, en los procesos naturales la auto-similitud fractal suele tener un carácter estadístico. El desarrollo de teorías basadas en la invariancia de las propiedades de un sistema dinámico a través de las escalas ha permitido que algunos patrones naturales que aparecen extremadamente complejos puedan mostrar una simplicidad subyacente que facilita su estudio. Por ejemplo, el proceso de la generación de lluvia, como en el caso de otros fenómenos atmosféricos, se considera un complejo proceso dinámico no lineal que puede resultar más sencillo de analizar estudiando las relaciones de escala de una de sus posibles manifestaciones, las series temporales de intensidad.

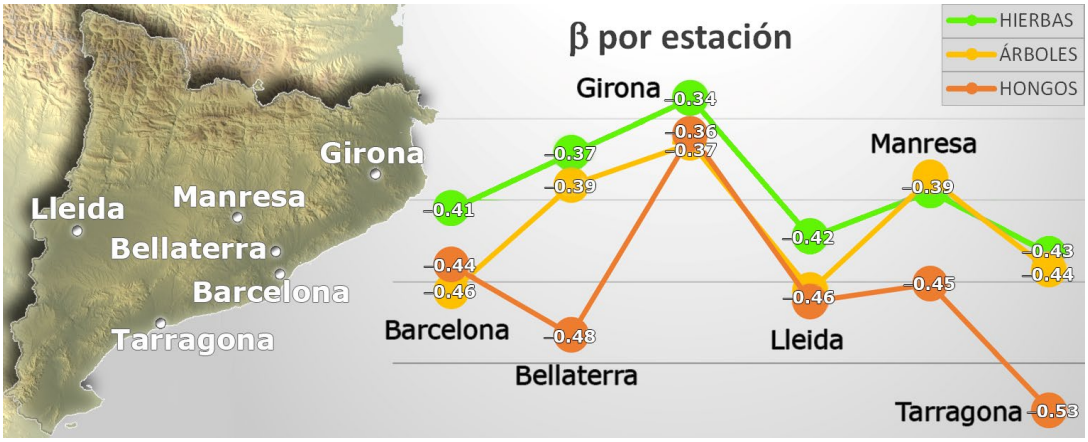

Figura 1. Valores medios del parámetro de escala simple β en estaciones aerobiológicas de Catalunya

De una manera análoga, en este trabajo se han analizado las relaciones de escala simple de las series temporales de concentración aérea máxima de polen y esporas de varias especies, medidas en seis estaciones aerobiológicas de Catalunya, con el fin de simplificar el estudio de procesos tan complejos como la polinización y la esporulación. Introduciendo la magnitud I_t para una cierta escala temporal t, calculada como la concentración máxima dividida por la duración de la medida, esta magnitud satisface una relación de escala simple si se puede describir mediante una distribución estadística que resulta idéntica para los dos miembros de la ecuación $I_t = \lambda^{\beta q} I_{\lambda t}$, en la cual λ es la relación de escala y q el orden de sus momentos estadísticos. Si el parámetro de escala β ha mostrado ser un buen indicador de la irregularidad del régimen pluviométrico, con valores cercanos al límite inferior de -1 en el caso de registros muy irregulares y más altos conforme aumenta la regularidad [1], para la concentración aérea máxima de polen los valores medios por localidad que se muestran en la Fig.1 resultan ligeramente más altos para las especies herbáceas que para el que procede de árboles, siendo los menores los correspondientes a las esporas. También se ha encontrado correlación entre β y el promedio y el coeficiente de variación de la suma de concentraciones diarias en un año, APIn, en cada estación.

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