Isabel Mercader
Premi UPC a la Qualitat en la Docència Universitària 2019

> La professora del Departament de Física Isabel Mercader va rebre el Premi UPC a la Qualitat en la Docència Universitària 2019 en reconeixement a la seva llarga trajectòria docent a la Universitat. Però no és la extensió temporal la que la fa mereixedora d’aquest Premi sinó la seva dedicació i qualitat contrastada durant els anys. No és fàcil mantenir un nivell alt durant tant temps, i la Isabel ho ha aconseguit perquè s’ha pres sempre la tasca docent amb una alta responsabilitat. Ara que ha decidit jubilar-se trobarem a faltar la seva energia i determinació en tot el que feia; un exemple a seguir per tots els que venen darrera.

Recordem alguna de les reflexions que va fer en el seu discurs d’acceptació del Premi que ja ens indiquen trets fonamentals de la seva personalitat.

«Quan vaig saber que em presentaven com a candidata al premi, pensava que no es consideraria la meva trajectòria mereixedora de cap distinció. La meva trajectòria docent no es caracteritza per "experiments docents singulars", jo només intento explicar amb serietat i entusiasme les assignatures que imparteixo. Per cert, el mateix que feu molts companys. >
Jo formo part d'un col·lectiu de professors i professores de la UPC, els físics, que sense fer massa soroll te la responsabilitat de donar als estudiants una part de formació bàsica, que és imprescindible en el desenvolupament de matèries més específiques dels seus estudis d'Enginyeria.

Els coneixements que nosaltres impartim estan inclosos típicament en assignatures amb programes molt densos que no donen peu a a masses floritures. Jo crec que aquest coneixements són el que són i el temps que tenim per transmetre’ls és el que és, i amb tot el respecte no podem organitzar la nostra tasca docent en estratègies que tinguin l’objectiu de que els estudiants vagin aprenent els conceptes a força de repetir i repetir certes accions controlades, fora d’hores lectives, amb l’esperi de que vagin aprenent sense adonar-se. Jo no soc partidària de muntar aquest tipus d’aprenentatge a la Universitat. Primer, per què fer això amb les assignatures tan denses com les que tenim trauria masses hores d’estudi a les assignatures del mateix nivell, però el que per mi és més important, crec que és molt millor que, els estudiants vagin aprenent a dissenyar els seus pròpies mètodes d’estudí per superar la dificultat de les diferents assignatures, per què això els prepararà millor per superar amb el seu esforç els reptes personals amb els que es trobaran quan desenvolupin la seva feina. La nostra tasca no és intentar que els estudiants arribin, agafats de la nostre ma, a uns mínims per sobreviure, això és fa abans i es d’agair als professors de primària que es deixin la pell per tirant cap endavant a nanos amb poca predisposició o poques capacitats, però a la universitat NO. Els estudiants han escol·lit les nostres titulacions amb continguts difícils, saben que el llistó està alt i han de comportar-se com adults, han d’escollir les nostres explicacions fetes amb rigor, han d’assimilar amb el seu esforç el que els hi transmetem i han de desenvolupar i utilitzar el seu enginy per anar endavant. Això no treu que la nostra interacció amb ells hagi de ser propera, cordial, humana i respectuosa i que intentem ajudar sempre al que ho demani».
Researchers Enrique García and Manel Soria, of the UPC, have created a numerical model that allows to evaluate and reproduce the evolution of the polar storms that take place in Saturn and the energy involved in its development, comparing them with the other types of storms observed previously. In this way, storms have been identified for the first time at different latitudes of this planet that are triggered by convection in deep clouds of water about 200 km below the visible clouds of the planet of the rings. The hot and humid gas rises very strongly to Saturn’s hydrogen atmosphere forming very dense clouds of ammonia, visible with the telescope. 

It all started on the night of March 29, 2018, when a Brazilian amateur astronomer captured with his telescope the presence of a small, but bright, white spot on the disk of the planet Saturn, near its north pole. A few days later the stain became large, reaching about 4,000 km in length and becoming the most remarkable detail of the disk of the planet of the rings. About two months later a second spot appeared, more towards the north of the planet, and in the following months sequentially, a third and a fourth spots, much closer to the polar region, on the banks of the famous Saturn hexagon, a phenomenon that had never been observed before.

During those months the spots moved at different speeds, dragged by the atmospheric winds that blow Saturn in strong currents to the east and west. While the first spot, located farther south, moved about 220 km / hour to the east, the one farther north was about 20 km / h to the west. This caused encounters between them, passing close to each other and generating, during their mutual interaction, atmospheric disturbances that spread around the entire polar region of Saturn.

The researchers Enrique García and Manel Soria, from Turbulence and Aerodynamics in Mechanical and Aerospace Engineering Research Group (TUAREG) of the Technical University of Catalonia-BarcelonaTech (UPC), have developed a numerical model with which, through supercomputers, you can reproduce the evolution of polar storms on Saturn and identify the conditions that have caused them. The work is part of an international project that has involved the Cassini space mission of the US, European and Italian space agencies, which was in orbit of the planet until September 2017. In addition, the project has had the Hubble space telescope, the PlanetCam camera of the UPB / EHU installed in the Calar Alto Observatory, the numerical simulations carried out by the UPC and the participation of a network of amateur observers who have contributed the images to follow day by day the evolution of the phenomenon.
numerical nanoswimmer model in which the simulation that it does includes all the atoms of the system, in contrast to the micro-swimmers, where phenomenological models are used. Our calculation is can therefore be described as first-principles or all-atom, and we have shown that propulsion emerges without any further approximation. Since the simulation of a quarter of a million water molecules is required, the use of BSC’s supercomputing resources has been very relevant.

In the accompanying image you can see a Fulleré C_{60} molecule of approximately 1 nanometer in diameter (in gray) immersed in 260,000 molecules of water (red oxygen, gray hydrogen). A diatomic dipole (yellow and blue) is linked to the fulleré. By means of optical radiation, fluorescent electronic transitions are induced in the dipole. These transitions are characterized by a periodic change in the distribution of charges of the dipole, which produces rapid reorientations of the water molecules in its immediate environment due to strong electrostatic interactions. This energy transfer gives rise to inhomogeneous heating in the surroundings of the fulleré, which is accompanied by a speed of propulsion in the opposite direction to heating, a phenomenon known as auto-thermophoresis, until now only observed on a micro-metric scale.

To answer these questions, the team formed by Martí Català and Clara Prats of the Department of Physics of the UPC and Pere-Joan Cardona of the Experimental Tuberculosis Unit (UTE) in the IGTP, has carried out a complex task of detectives through a mathematical model to combine biological, anthropological and historical data to offer answers. The result is surprising: not only humans have survived despite TB infections, but they probably have played a key role in the current form of human society as we know it.

The study is a collaboration between Institut de Recerca Germans Trias i Pujol (IGTP), el Centre de Medicina Comparativa i Bioimatge (CMCiB-IGTP), CIBERES and the Technical University of Catalonia (UPC). The long story about the battle between people and bacteria is considered: When the paleolithic disease appeared, population growth had fallen from 1% to only 0.003%, probably small groups became infected and were dying. The model shows that at that time, when infant mortality was 50%, women had to have two surviving children (that is, four deliveries) to maintain the population. With the arrival of modern strains of Mycobacterium tuberculosis, the ailment became more deadly and increased these figures to 3 surviving children, or 6 pregnancies, in order to maintain the species. The reason why the population went from hunter-gatherer dynamics to settlement and agricultural life has not been understood, at a time when the habitable parts of the world were limited from the Indian Subcontinent in Australia, due to glaciation generalized. So far there has been no obvious reason to explain this change.

> Tuberculosis (TB), caused by the Mycobacterium tuberculosis complex (MtbC) microbe, has been infecting humans since the old stone age, or paleolithic period, when people lived as hunter-gatherers, organized in small groups. About 43,000 years ago, during the Neolithic period, people began to settle and create farms; Around this time, the most modern form of tuberculosis developed. TB is a devastating disease, it has killed about 1,000,000,000 people in the last 200 years, the equivalent to the current population of the entire American continent, and raises interesting questions. Why didn’t the small population of the first humans die? How have tuberculosis and its guests survived? And why does it seem that women are more resistant than men to ailment?

Clara Prats and Martí Català of the BIOCOM-SC research group study the effect of tuberculosis on human evolution.

Origin of tuberculosis in the Paleolithic predicts unprecedented population growth and female resistance.

Pere-Joan Cardona, Martí Català & Clara Prats
https://www.nature.com/articles/s41598-019-56769-1
An international collaborative project has identified a new form of cell division caused by protein waves. The discovery that supposes new applications in the field of synthetic biology and can serve as a paradigm to implement a self-organized proliferation strategy in artificial cells.

The researchers of the research group in Computational Biology and Complex Systems (BIOCOM-SC) of the Physics Department of the Technical University of Catalonia-BarcelonaTech (UPC) Sergio Alonso and Francesc Font - currently a researcher at the Centre de Recerca Matemàtica - in collaboration with Scientists from the Biophysics group of the University of Potsdam (Germany) have discovered a new form of cell division that is triggered by protein waves within cells. The study has recently been published in the journal Proceedings of the National Academy of Sciences (PNAS).

The biophysicists team of the University of Potsdam has observed, with microscopic techniques, dynamic changes in the cytoskeleton to giant cells of the amoeba Dictyostelium discoideum. Under certain conditions, accumulations of cyto-skeletal proteins can move through the cell in a waveform. If this protein wave reaches the edge of the cell, it pushes the membrane around the cell out. This deformation is getting stronger and stronger and leads, finally, to a daughter cell separating itself from the rest of the giant cell, with the characteristic measure of the wave that causes the division.

For its part, the team of researchers from the Department of Physics of the UPC has developed a computer model that reconstructs this cell division caused by protein waves in simulated cells. In this way, a better understanding of the prerequisites necessary to generate this process can be obtained. This new cell division mechanism opens the door to possible applications in synthetic biology - in the design and construction of artificially produced cells - and can serve as the basis for implementing a self-organized proliferation strategy in artificial cells.

Evidence of supersolid quantum phase using quantum Monte Carlo methods

M. C. Gordillo, Jordi Boronat

> Jordi Boronat, Director of the department of Physics, together with M. C. Gordillo from the University of Pablo de Olavide in Seville found evidences of a supersolid quantum phase with hexatic correlations using quantum Monte Carlo methods.

Probably, one of the most exciting phases in Nature is the supersolid one, a system that at the same time has the spatial long-range order of a crystal and an off-diagonal long range order typical of superfluids. Research trying to find the key signatures of this theoretically predicted state has been elusive for long time. The natural candidate for this state is Helium, which is known to remain liquid even in the limit of zero temperature. In bulk Helium it has not been possible to confirm its existence yet. However, Helium, is strongly adsorbed on graphite forming successive layers of a quasi two-dimensional nature. Several experiments found that in the second layer of Helium on graphite there could be a supersolid phase but no theory was able to account for these observations. In our recent work, we identified this supersolid layer as a registered crystal to the first inert layer and, importantly, matching the coverage range observed in the experiments. Moreover, we found for the first time a superfluid hexatic phase induced by the corrugation with the first layer.
The Barcelona metropolitan area (BMA; 3.2 M inhabitants) has an integrated urban water cycle management. Different types of treatment plants are located along the drinking, sewerage and reuse networks where specific treatments are applied to guarantee a good enough standard of the water quality. The presence of radionuclides in treatment plants and in the aquatic environment is well known. Primordial and daughters, cosmogenic, global fallout and nuclear-legacy radionuclides can be found in the urban water cycle. Moreover in nuclear medicine (NM), short-lived radionuclides are administered to patients, excreting part directly into the sewage network and entering into the urban water cycle. Thus, the levels of radionuclides in waters and materials from water treatment plants were experimentally checked in the BMA in order to understand the behaviour during the water treatment and to perform a risk assessment.

An integrated study focused on the study of the radionuclides levels at different three types of water treatment plants from the same network was carried out. A total of 233 samples were taken at 1 drinking water treatment plant (DWTP), 7 wastewater treatment plants (WWTPs) and 1 reclaimed water treatment plant (RWTP). The concentrations were determined by gamma-spectroscopy techniques after acquisitions performed by high-purity germanium detectors. Primordial and daughters radionuclides were found in materials from the DWTP studied and the highest specific activities found for sludge, sand and reverse osmosis brine corresponded to K-40. Nevertheless, the maximum concentration in the case of granular activated carbon was found for U-238. Moreover cosmogenic Be-7 and fallout Cs-137 were found in sludges. A total of 5 different NM radionuclides were found in the analysis carried out in the samples from the 7 WWTPs. In the case of water and sewage sludge the highest maximum values and detection frequencies corresponded to Tc-99m and I-131. Moreover Ga-67, In-111 and I-123 were found but showing significantly lower levels. The detection frequencies and the mean levels found at the WWTPs of Ga-67, Tc-99m, In-111 and I-131 agreed with the NM radionuclides total activity administered in the region studied. Furthermore the concentrations and detection frequencies were significantly higher in the sewage sludge samples taken at the very large-sized WWTP-1 (325,000 m3/d), partially explained by their low sludge age. Medically-derived I-131 was also found in reclaimed water for reuse from the RWTP and materials from DWTP, which represent novel contributions to the current knowledge in this field.

Taking into account the present findings some considerations from the radiological protection point of view can be done. Despite the presence of radionuclides in the DWTP materials, they do not pose a radiological risk. In the case of the WWTPs and the RWTP studied, the levels found in waters and materials do not represent a significant risk, however, I-131 concentrations were pointed out as the most significant. With the aim to achieve a better understanding of I-131 behaviour in WWTPs and predict the I-131 levels novel methods of I-131 partitioning analysis as well as prognosis models were adapted successfully to a WWTP. I-131 partitioning results pointed out that the settling fraction predominates in the reactor while in the rest of the WWTP samples dissolved iodide fraction was the most significant. Furthermore the activated sludge reactors from WWTPs were revealed as the key step for I-131 removal from wastewater. Specifically, reactors with the highest total nitrogen kjeldahl removal were also the most effective for I-131 reduction. Regarding the I-131 modelling a total of 82 % of simulated data fit with the experimental results in the sewage effluent within uncertainties.
Ferroelectric materials are endowed with fascinating functional properties from the technological point of view. Consequently, they have promoted the design of a vast number of ferroelectric-based devices. However, some physical phenomena in these materials represent yet a challenge for solid-state physics. For instance, understanding the correlation between microstructure and functional properties as well as the relaxation dynamics from the high sintering temperatures to the working temperatures are two of these challenges. The likelihood of functional properties enhancement leads to countless studies on these subjects.

In this context, the thesis focuses on the study of the dielectric relaxation dynamics of both ordinary and relaxor ferroelectrics. The phenomenological Vogel-Fulcher-Tammann (VFT) equation has been used for decades to parameterize the dielectric relaxation dynamics of ferroelectrics, although there is no theoretical description that justifies the prevalence of this empirical relationship over other parameterizations. Notwithstanding the good fitting results of VFT equation to parameterize the dielectric relaxations, this work evidences that there is none statistical criterion showing a prevailing parameterization to fit the dielectric relaxations in ferroelectrics. The dynamics character of the low temperature dielectric relaxation in ordinary ferroelectrics is also evidenced, refuting previous hypotheses related to the origin of this dielectric anomaly.

Since different parameterizations provide different explanations for the physical phenomena governing the dielectric relaxations, choosing a parameterization implies a biased analysis. This fact justifies the use of a new unbiased, model-free methodology to study the dielectric relaxations in ferroelectrics. Therefore, a methodology based on the direct experimental data processing is validated. Hence, changes in the dynamical response and the freezing temperature can be identified directly from data processing. Besides, as a novelty of this work, a new parameter associated with the composition–order of the relaxor systems is introduced. In fact, the introduction of this parameter and its relationship with the configurational entropy on the studied systems is one of the most reliable results.
> Álvaro Meseguer has published the book entitled "Fundamentals of Numerical Mathematics for Physicists and Engineers". Álvaro Meseguer of the Nonlinear Fluid Dynamics (DF) research group has recently published a book based on his experience in teaching Numerical and Computational Methods in Physical Engineering at the UPC. Much of the material in the book Fundamentals of Numerical Mathematics for Physicists and Engineers is derived from the notes of two courses on numerical methods taught for many years to undergraduate students in Physical Engineering at the Universitat Politècnica de Catalunya (UPC) BarcelonaTech. Its volume is scaled to a one-year course, that is, a two-semester course. Part I is aimed at undergraduate and graduate students who have a solid foundation in differential and integral calculus in a real variable. Part II is aimed at slightly more advanced undergraduate or graduate students with a broader mathematical basis, which includes multivariate calculus, ordinary differential equations, functions of a complex variable, and Fourier series. In both cases, students are assumed to be familiar with the basic commands and functions of Matlab.

> Winners of the price: “Convocatòria 2020 d’ajuts a la formació per estudiants del Màster en Enginyeria Física de la Universitat Politècnica de Catalunya-BarcelonaTech”.

The three prices of 1000€ each were awarded to the following students and their corresponding Master’s Final Project (TFM).

- **Nica Gutu**, TFM: Biochemical model for the amoeboid motion of Dictyostelium discoideum cells.
- **Jordi Pera**, TFM: Highly degenerate Fermi gases.
- **Paula Pàmies**, TFM: New insights into the optical control of domain wall motion in ferroelectrics.

The Department gives his congratulations to the winners. We hope you all have a brilliant career ahead of you!