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Índice

1. Influence of the temperature on the spectral resonances of β-Ga2O3:Cr nanowire-based optical microcavities

Daniel Carrasco Madrigal

A field of great interest for photonic applications is semiconductor micro and nanowires, since thanks to the modification of the composition of the material or the creation of artificial optical structures it is possible to control its optical properties.rnOne of the photonic structures, with a wide range of applications, are optical micro- and nanocavities based on Bragg mirrors (distributed Bragg reflector, DBR) that consist of creating periodic modulations of the refractive index in a dielectric medium. The creation of this type of structures in semiconductor micro- and nanowires broadens their potential applications as light sources at the micro and nanoscale. In this work, optical cavities based on DBRs created in microwires of gallium oxide in its monoclinic phase doped with Cr3+ (β-Ga2O3:Cr) that emit photoluminescence (PL) very efficiently in the red-IR range due to the superposition of a broad phonon-assisted band and two emission lines (R-lines) are analyzed. The combination of this broad band and the cavity results in Fabry-Perot type optical resonances peaks. The position of this resonance peaks and R-lines are sensitive to changes in the temperature of the nanowire and can be observable in the PL spectra. This effect on the resonance peaks will be studied both theoretically by means of FDTD simulations, and experimentally by heating the wire irradiating locally with a laser in a confocal optical microscope. rnThe results show a novel design of a nano temperature sensor from 150K to 550K with a precision around 1K and a high spatial resolution that can be used in harsh environments and for high-power electronics and photonics applications thanks to the high thermal and chemical stability of the β-Ga2O3.

2. Predictability of Population Fluctuations

Rodrigo Crespo Miguel

Population dynamics is affected by environmental fluctuations (such as climate variations), which have a characteristic correlation time. Strikingly, the time scale of predictability can be larger for the population dynamics than for the underlying environmental fluctuations. Here, we present a general mechanism leading to this increase in predictability. We considered colored environmental fluctuations acting on a population close to equilibrium. In this framework, we derived the temporal auto and cross-correlation functions for the environmental and population fluctuations. We found a general correlation time hierarchy led by the environmental-population correlation time, closely followed by the population autocorrelation time. The increased predictability of the population fluctuations arises as an increase in its autocorrelation and cross-correlation times. These increases are enhanced by the slow damping of the population fluctuations, which has an integrative effect on the impact of correlated environmental fluctuations. Therefore, population fluctuations predictability is enhanced when the damping time of the population fluctuation is larger than the correlation time of the environmental fluctuations. This general mechanism can be quite frequent in nature, and it largely increases the perspectives of making reliable predictions of population fluctuations.

3. Generating baryon asymmetry with metric perturbations

Alfredo Delgado Miravet

We make the observation that the gravitational leptogenesis mechanism can be implemented without invoking new axial couplings in the inflaton sector. We show that in the perturbed Robertson-Walker background emerging after inflation, the spacetime metric itself breaks parity symmetry and generates a non-vansihing Pontryagin density which can produce a matter-antimatter asymmetry. We analyse the inflationary and reheating scenarios in which the produced asymmetry is enhanced.

4. Realistic treatment of nuclear structure in the neutrino-nucleus interaction

Tania Franco Muñoz

An unprecedented activity has been unleashed in recent years to determine neutrino properties and their interactions. It has been firmly established that neutrinos oscillate and hence are massive particles. Some of the oscillation parameters, such as the neutrino mixing angles, have been measured with some precision, but other properties remain to be determined, such as their masses or the phase that quantifies the possible charge-parity violation. These are some of the goals of the new generation of accelerator-based neutrino oscillation experiments NOvA, DUNE and HyperKamiokande, with which neutrino physics enters a new 'Precision Era'.rnrnThe fact that all neutrino oscillation experiments use complex nuclei as target material in the detectors, for example mineral oils, water or liquid argon, complicates the analysis of the results since nuclear effects must be considered. In the energy region covered by the neutrino oscillation experiments, the neutrino-nucleus scattering cross section is not very precisely known, so that it is currently one of the largest contributions to the error. This is what makes the study of neutrino-nucleus interactions a hot topic and brings theoretical nuclear physics to the stage.rnrnAmong all the reaction mechanisms that take place in neutrino experiments, we focus on the quasielastic channel, where the scattering off a bound nucleon which is knocked out from the nucleus occurs. This process is studied within a realistic nuclear framework, using a state of the art relativistic mean-field based model for the description of the nuclear dynamics and final state interactions within a quantum mechanical framework. Residual interactions between the bound nucleons through pion exchange are also included. We extend the usual treatment of QE scattering, based on a one-body current operator, by incorporating a two-body meson-exchange current one. The key contribution of our work is the incorporation of this meson exchange current contribution.

5. Vertical accelerations in cosmologicalrnsimulations of Milky Way sized galaxies

Begoña García-Conde Navarro

Cosmological simulations with high resolution are recently used to study the dynamics of the Milky Way. In our previous work we have analyzed the simulation GARROTXA and have found phase spirals in the Z-Vz plane. Such features are an indication of vertical perturbation of the galactic disk. To discern the cause of these phenomena and having such a complex disk with several satellites orbiting the system, we study how transient and non-axisymmetric structures in and around the main galactic system affect and perturb the disk. We calculate the accelerations that each of these structures -both separately and as a whole- produce on the galactic plane. We find that satellites do not dominate the acceleration field, but the stars at radii from 10-15 kpc and gas in from 10-15 kpc. At recent times, the overall accelerations reach it maximum as the combination of all components, shortly after several pericenters from the satellites of the system. We suggest that even though the satellites do not dominate the acceleration over the galactic plane, they produce perturbations in both the dark matter halo and the infalling gas that may have an impact on the galactic disk.

6. Magnetic domains tune faster out-of-equilibrium critical dynamics

Isidoro González-Adalid Pemartín

Reaching thermal equilibrium fast is an important problem in science and industry. For this reason, the non-equilibrium relaxation has been very studied during the last decades. In fact, the attention received by the counterintuitive Mpemba Effect [E. B. Mpemba and D. G. Osborne, Phys. Educ. 4, 172 (1969)], allowing to cool down faster the hotter of two systems (or heat up faster the cooler system), is reasonable. Indeed, we now understand the general conditions that allow a faster cooling, or faster heating, in a variety of systems like granular matter, spin glasses, or classical and quantum Markovian systems. This knowledge allows to develop better strategies for cooling, or heating, a system. In particular, Amit and Raz have recently designed a faster heating protocol for systems with timescale separation [A. Gal and O. Raz, Phys. Rev. Lett., 124, 060602 (2020)].rnrnHowever, a timescale separation is not present in a second-order phase transition, where critical slowing down evidences a continuum of timescale. In this situation, understanding the mechanism that governs the dynamics is the key to potentially control the evolution. The size of the ordered domains when the system enters the symmetry-broken phase is a natural candidate as a driver for this mechanism.rnrnIn our work [I. González-Adalid Pemartín, et al. Phys. Rev. E, 104, 044114 (2021)], we focus on the study of the ferromagnetic two-dimensional Ising spin model. We study, through numerical simulations, an unexplored out-of-equilibrium heating protocol, in which the bath temperature starts below the critical temperature, in the ferromagnetic phase, and is later heated above the critical point, in the paramagnetic phase. We show that a faster relaxation can be reached in absence of timescale separation by manipulating the system's internal structure of ordered domains (related with the coherence length) thanks to this excursion in the symmetry-broken phase.

7. Out-of-equilibrium thermodynamics of an active poroelastic system

Luque Rioja

Living systems dissipate energy constantly as they perform essential functions. Because of their ordered and self-organized dynamics, these processes frequently result in complex behaviors that can be classified as non-thermal processes. However, it can often be challenging to tell whether a process' dynamics are significantly different from those of a thermally driven process. rnrnHere, we present an active-poroelastic theoretical framework to represent chromatin as an active-elastic solid coupled to a permeating fluid. Based on experimental data suggesting large-scale correlated mobility of chromatin inside the nuclei of live differentiated cells, we include the active stress into a two-fluid model that accounts for the spatiotemporal dynamics of the nucleus. This system is affected by both passive thermal fluctuations and active scalar events, such as condensation and decondensation, which we name spikes. The coupled set of equations showing the presence of emergent processes is simulated in this instance.

8. How different are Sudden Stratospheric Warmings with and without a North Atlantic response?

Verónica Martínez Andradas

Sudden stratospheric warmings (SSWs) are extreme weakenings of the wintertime polar vortex and can alter the surface weather for over two months. This is why they are very useful for subseasonal to seasonal predictions, but there is still much uncertainty on how the tropospheric response occurs. We use ERA5 reanalysis data for the period 1950-2020 to examine differences in the atmospheric circulation during SSWs followed by an equatorward (EQ) and poleward (POLE) shift of the North Atlantic jet stream. Our results show a stronger and more persistent Northern Annular Mode (NAM) signal in the lower stratosphere for EQ than for POLE, beginning 2 weeks before the onset date. In the troposphere, there are significant negative NAM anomalies in EQ starting several weeks before the SSWs: at negative lags, the negative NAM is associated with circulation anomalies in the polar and Pacific sectors, while at positive lags is associated with the equatorward shift of the North Atlantic jet. We also find that many POLE cases occur during strong La Niña winters, potentially reducing the subseasonal to seasonal predictability given by SSWs.

9. Collective behaviour of energy depot repulsive particles

Juan Pablo Miranda López

In this work we consider an active particle model, that reproduces the motion of microscopicrnbiological objects, such as cells or bacteria, that is described with Langevin dynamics. The particlesrnare able to take energy from their environment, store it into an internal energy depot and convert itrninto kinetic energy on the direction of motion[1].rnThis model uses a velocity dependant friction function. We study the different diffusion regimesrnvarying the parameters of the model. We implement a repulsive interaction with a WCA potential,rnand study how it affects the dynamical properties of the model.rnrnWe have studied a two dimensional suspension of repulsive particles, where the interaction be-rntween the particles is implemented with a WCA potential. We have studied both dynamical andrnrnstructural features of the system. The main studied structural feature is a phase transition between anrnordered an a disordered state for different volume fractions φ and values of q0.

10. A thermomechanically coupled flowline model

Daniel Moreno Parada

Ice-stream flow and grounding line migration remain as a main obstacle for glaciologists and manifests a clear a gap in our understanding of the physical phenomena underlying such behaviours. Here we present a thermomechanically-coupled flowline model to study a number of aspects regarding ice flow temporal variability and grounding line dynamics. Unlike previous studies, we consider the basal friction dependency on the sliding velocity and explicitly solve a coupled advection-diffusion Fourier heat equation. This allows us to quantify the dynamic and thermal contributions independently. Consequently, a solid understanding of the physical system will shed light on our comprehension of the relevant processes that determine the evolution of ice streaming and grounding line motion. We herein present a description of the numerical model and the successful results when tested against prior benchmark studies.

11. Electronic structure of defect-modulated MoS2: HER catalytic activity

Jairo Obando Guevara

The actions aimed to mitigate anthropogenic global warming should not be limited to lessening the still available fossil resources, but ideally, must envisage a transition towards zero carbon emission fuels. Thus, the development of hydrogen fuel technology obtained electrochemically through the hydrogen evolution reaction (HER) is presented as a green solution to the global power demand. Due to this reason, the search for low-cost electrocatalysts is fundamental.rnrnThe discovery of graphene and the study of its outstanding properties triggered a renewed interest in the so-called two-dimensional (2D) materials and related layered materials. A remarkable example of graphene-like materials is the transition metal dichalcogenides (TMDs), these materials show a wide range of electronic, optoelectronic, and mechanical emerging properties. Particularly, MoS2 has been established as a feasible substitute for state-of-the-art platinum catalysts. Defect engineering is essential in order to achieve operational Pt-like performance. It is found that exposed Mo sites, present as coordinatively unsaturated sites at the edges or in native chalcogen-vacancies at the surface, are essential for increasing hydrogen adsorption. Nevertheless, experimental evidence on how the valence band (VB) is modified with the inclusion of vacancies is lacking.rnrnIn this work, we present Angle-Resolved Photoemission Spectroscopy (ARPES) results of the MoS2 electronic structure tunning and its impact on the HER activity. We show that annealing in UHV conditions leads to the desorption of sulphur atoms. The produced vacancies introduce states within the VB previously undetected yet predicted theoretically. Finally, we elucidate how hydrogen interacts with the vacancies by exposing the surface to hydrogen gas at room temperature while following the evolution of the defect bands.

12. Cosmological particle production in the lab

Álvaro Parra López

One of the consequences of considering quantum field theory in a time-dependent background geometry is gravitational particle production, which is especially important during inflation. Since this mechanism requires no interaction between fields, it has been proposed for explaining the observed abundance of dark matter. The difficulty of experimentally accessing such scenarios in a direct way, makes the possibility of simulating them in the laboratory very exciting. This has been the objective of the analogue gravity program, which has mainly focused on the use of Bose-Einstein condensates as platforms for dynamically resembling scalar fields in flat FLRW universes.rnrnThe goal of the thesis is two-fold. First, we want to study cosmological particle production of different fields, such as scalar, vector or spin-2, as well as the influence of Ricci scalar oscillations during reheating, the importance of the choice of vacuum in non-stationary situations or tachyonic initial conditions. Second, we want to find systems that allow us to simulate these cosmological scenarios in order to answer fundamental questions about quantum fields in curved spacetime.rnrnIn our first works, we were able to calculate particle production in a FLRW geometry for a scalar field within a slow-roll inflationary model, considering the tachyonic regimes in which the system falls during reheating and using a novel prescription for the instantaneous vacuum, rather than the usual adiabatic vacuum.rnrnAt the same time, we extended the already mentioned analogy in BECs to FLRW universes of any spatial curvature, and provided experimentally feasible observables for particle production detection in the laboratory. As a direct application of our theoretical methods and in collaboration with a group of experimental colleagues, we have realized FLRW spacetimes with positive and negative spatial curvature and confirmed particle pair production driven by a power-law scale factor in a BEC experiment.

13. Optimization of graphene-based gas sensors by ultraviolet photoactivation.

Álvaro Peña

Nitrogen dioxide (NO2) is a potential hazard to human health at low concentrations, below one part per million (ppm). NO2 can be monitored using gas sensors based on multi-layered graphene operating at ambient temperature. However, reliable detection of concentrations on the order of parts per million and lower is hindered by partial recovery and lack of reproducibility of the sensors after exposure. We show how to overcome these longstanding problems using ultraviolet (UV) light. When exposed to NO2, the sensor response is enhanced by 290% - 550% under a 275 nm wavelength light emitting diode irradiation. Furthermore, the sensor's initial state is completely restored after exposure to the target gas. UV irradiation at 68 W/m2 reduces the NO2 detection limit to 30 parts per billion (ppb) at room temperature. We investigated sensor performance optimization for UV irradiation with different power densities and target gases, such as carbon oxide and ammonia. Improved sensitivity, recovery, and reproducibility of UV-assisted graphene-based gas sensors make them suitable for widespread environmental applications.

14. Spin textures and topological Hall effect in bilayer of La0,7Sr0.3MnO3 and SrIrO3

Andrea Peralta Somoza

Texturas magnéticas como los esquirmiones han atraído mucha atención académica debido a su potencial aplicación en dispositivo de almacenamiento de información. Estas texturas magnéticas producen una señal antisimétrica en las medidas de resistencia transversal conocida como efecto Hall topológico. Sin embargo, existe un debate en torno a la conexión de este efecto topológico y las texturas magnéticas que se observan en microscopia. En este contexto decidimos realizar medidas de efecto Hall en bicapas de La0.7Sr0.3MnO3 y SrIrO3, acompañadas con imágenes de microscopía de fuerza magnética (MFM) y de dicroísmo magnético circular (PEEM). Como resultado encontramos un efecto Hall topológico considerablemente grande a baja temperatura, además de imágenes de microscopía de las texturas magnéticas utilizando las dos técnicas mencionadas. Además, observamos que el efecto Hall topológico puede ser controlado a través de la historia magnética del material, algo nunca reportado hasta ahora. Sin embargo, observamos que las texturas magnéticas están presentes en el material haya o no efecto Hall topológico, de manera que las texturas magnéticas no son las únicas responsables de dicho efecto. Un posible origen de este efecto Hall topológico serían las fronteras quirales que se observan a altos campos. Este trabajo abre la puerta a futuras investigaciones en torno al control del efecto topológico y su verdadero origen. Además, en línea con la controversia actual en torno a este campo, reafirma el hecho de que las imágenes de microscopia no proporcionan suficiente información para conectar el efecto Hall topológico con las texturas observadas.

15. Selective contacts for undoped photovoltaicrncells fabricated by high pressure sputtering

Francisco José Pérez Zenteno

Nowadays, with the spiraling effects of climate change, the solar photovoltaic energy is one of the best alternatives to reduce the greenhouse gas emissions. Since the last decade, the cost per kWh produced by photovoltaics around the world has decreased from $0.380 to $0.048[1]. One key reason for this paramount achievement is the technological maturity of Si-based semiconductors. rnrnMany researchers have been researching new materials/structures that could overcome the intrinsic limitations of the homojunction technology (use of toxic and/or dangerous chemicals, interlayer recombination, high temperature process, etc.). One of the possible options that has generated great expectation is the introduction of heterojunction structures, particularly the Dopant-free Asymmetric Heterocontact (DASH) structure. To fabricate this kind of cells, it is necessary to have structures that produce selectivity of carriers: electrons should flow to the Electron Selective Contact (ESC) while the holes are repelled and vice versa. Some materials that present this behavior are Transition Metal Oxides (TMO). rnrnTo deposit TMOs on Si wafers, there are many techniques such as Atomic Layer Deposition, Chemical Vehicle Deposition, or sputtering. However, these technologies might damage the interlayer between the deposited thin film and the substrate. This would reduce the efficiency of the cell since the damage in the interlayer increases the carrier recombination. A possible approach to reduce the damage is to thermalize the atoms before they arrive to the surface of the substrate. This could be done by increasing the working pressure via the uncommon High-Pressure Sputtering (HPS). In this presentation, I will show the result of my research about the deposition, electrical and structural characteristics of TMO thin films that could behave as selective contacts, particularly TiOx and ITO.rnrn[1] IREA. (2021). Renewable Power Generation Costs in 2021.

16. First ever weather network on Mars

María Ruíz Pérez

For the first time ever, we examine the atmospheric pressure and air temperatures obtained by two different weather stations observing simultaneously on an extraterrestrial body (Mars): the Rover Environmental Monitoring Station (REMS) onboard NASA Curiosity rover inside Gale Crater and Temperature and Wind for InSight (TWINS) onboard NASA InSight lander on Elysium Planitia, both developed at Centro de Astrobiologia (Spain). The meteorological model MRAMS had been used to better understand the martian meteorology in those two very different environments. MRAMS model results are shown to be in good agreement with both REMS and TWINS observations when considering the uncertainties in the observational data set. The good agreement provides justification for utilizing the model results to investigate the essential meteorological environment features both in Gale Crater and Elysium Planitia (Mars). rnrnAs expected, both REMS and MRAMS show during nighttime air temperatures up to 10 K warmer for recent years (MY35-36) compared to postlanding years (MY31-32), when the rover was exposed to cold air masses at the crater floor. Pressure decay as the rover Curiosity climbs Mt. Sharp since the atmosphere column above a unit area shortens as altitude. Our results help to better understand the martian meteorology inside Gale Crater, revealing changes in pressure and temperature driven by the change in altitude, and confirming the hypothesis of Rafkin et al. 2016 about the existence of a pocket of cold air at the bottom of the crater.Comparing REMS vs TWINS, pressure is bigger at Gale crater (-4,500 m) due to elevation changes vs Elysium Planitia (-2,600 m). Temperature differences between model and observations are due to height changes: MRAMS at 14.5 m and instruments at 1.5 m.

17. Vector Diffractive Optical Element as a Full-Stokes Analyzer

Ángela Soria García

The real-time characterization of the state of polarization of a light beam is important in a variety of optics and photonics applications. We have designed a device which is able to simultaneously evaluate the full Stokes vector of an incident light beam. It consists of a sectorized Vector Diffractive Optical Element (VDOE). Each sector has a Fresnel zone plate, a polarizer and a quarter-wave plate, if required. Using vector Rayleigh-Sommerfeld approach, we have obtained the intensity distribution at VDOE focal plane. Then, employing as many photodetectors as sectors of the VDOE, we have determined the Stokes vector and we have compared it with the incident one.rnWe have also developed a procedure to remove diffractive effects since the VDOE scatters a fraction of light towards other detectors. Moreover, as we have observed that the uncertainties vary smoothly and represent systematics errors caused by the limited spatial resolution of the VDOE, we have made linear fits to reduce them. With this corrections, the error in the estimation of the Stokes parameters presents an averaged value of 0.006%.rnFinally, to experimentally evaluate the performance of the design, we have manufactured a VDOE using non-ideal Fresnel zone plates and polarization elements. Our analysis shows that the experimental device behaves as expected and it reproduces well the Stokes vector of the incoming beam, reaching an averaged error of 3.33%. This uncertainty is mostly caused by real polarization elements, spatial resolution of the fabricated device or the inhomogeneity of the light beam on the VDOE aperture.

18. Rate-Induced Tipping of the West-Antarctic Ice Sheet

Jan Swierczek-Jereczek

The retreat of the West-Antarctic Ice Sheet (WAIS) represents one of the largest sources of potential future sea-level rise, as large-scale ice loss may be abrupt due to an underlying bifurcation. Here we assess the potential for rate-induced tipping of the WAIS by stressing the discrepancies between ice-sheet responses to quasi-equilibrium and transient forcings. It appears that the higher the rate of forcing, the lower the warming needed for a collapse. In particular, we show that warming rates of intermediate-emission scenarios already lead to a collapse of the WAIS for levels of warming that are 10% lower than the bifurcation point.

19. Information and Thermodynamicsrnin quantum hybrid systems

Jorge Tabanera Bravo

At the nanometric scale, the laws of Thermodynamics have been a challenge since Maxwell's time. Since he proposed the Demonrnparadox, there has been an intuition of the importance of Information Theory in these laws, but we still need to improve ourrncontrol of experiments at the nanoscale. Hybrid systems combine quantum and classical degrees of freedom in such a way that werncan directly observe both energy flows between the two and dissipation phenomena. This makes them excellent experimentalrnplatforms for thermodynamic analysis. In this work we use the information flow formalism to evaluate entropy generation on arnrealistic devices and propose a particular experimental implementation.

20. Development of a low-cost and versatile whole-eye optical beam scanner for OCT

María Pilar Urizar Ursua

Performing whole-eye optical coherence tomography (OCT)scans is important in a wide range of applications, e.g., ocular biometry for cataract surgery and myopia studies. Conventional OCT systems have limited capabilities of performing a whole-eye scan as anterior and posterior segments of the eye require different imaging configurations, due to the refraction of the optics of the eye. While for imaging the anterior segment a telecentric displacement of a focused beam is often used, for imaging the retina the most common configuration involves pivoting a collimated beam at the pupil plane of the eye. The combination of galvanometric scanners with an electrotuneable lens (ETL) has been recently proposed to perform quasi-simultaneous whole-eye imaging by dynamically changing the focal plane during the scan but having a constant pivot point in front of the cornea. Adding more dynamic versatility in the scanning configuration would result in improved image quality. In this work, we present the development of a versatile and low-cost optical beam scanner based on three ETLs and a DC motor that allows for a quasi-simultaneous switch between the anterior and posterior segment imaging configurations, i.e., performing dynamic changes in both requirements, focal plane and pivot point, of each scanning configuration. This, in turns, facilitates high-quality OCT imaging of the whole eye. We have analytically and numerically characterized the relationship between the focal lengths of each ETL to obtain an optical design of the system capable of imaging the whole eye by performing at both imaging configurations without requiring mechanical changes on the system. Its optical and imaging performance have also been analytically and experimentally characterized. We have also proven the capability of the proposed device to perform as a beam scanner in a custom swept source OCT system by imaging a whole-eye scan of an ex-vivo rabbit eye.