Grupo Interdisciplinar de Sistemas Complejos

X workshop

Escuela Politécnica Superior, Universidad Carlos III de Madrid
February 8th, 2013

Address: Av. de la Univesidad 30, Leganés, Madrid
Edficio Agustín de Betancourt (Building 1), Room 1.2.C16 Adoración de Miguel (2nd floor)

Program

10:00	Francisco Domínguez-Adame	Mythbusters: Paradoxes from the dawn of quantum physics.
10:30	Edgar Roldán	Detecting active processes from spontaneous oscillations of Ear Hair bundles.
11:00	Edoardo Vivo	Strong anisotropy in surface kinetic roughening: theory and experiments.
11:30	Coffee break	
12:00	Carlos Rascón	Capillary emptying and short-range wetting.
12:30	Antonio Rodríguez	Bloch oscillations of two electrons interacting by the Coulomb potential.
13:00	Giulio Cimini	Temporal effects in the growth of networks.
13:30	Lunch	
15:30	Saúl Ares	Formation and maintenance of nitrogen fixing cell patterns in filamentous cyanobacteria.
16:00	Pablo Rodríguez-López	Casimir effect between topological insulators.
16:30	Coffee break	
17:00	Svetozar Nesic	Intrinsic noise on Fisher fronts.
17:30	Ana Moreno	Ripple dynamics driven by stress induced solid flow.
18:00	Conclusion	

Abstracts

Mythbusters: Paradoxes from the dawn of quantum physics
Francisco Domínguez-Adame (UCM)

Quantum physics is an odd theory that works remarkably well to explain the world at atomic scale. The advent of nanotechnology opens the door to test some of its predictions in a controlled way. In this talk I will present two of these paradoxes in the context of nanophysics. The first untested prediction came from von Neumann and Wigner in 1929, regarding bound states in the continuum. I will report the formation of these exotic states in quantum nanorings driven by AC fields. The second prediction was also established in 1929 by Klein, who discovered that Dirac electrons undergo anomalous tunneling at high potential barriers. Electrons in graphene close to the Fermi energy can be described as massless Dirac particles. Klein tunneling manifests itself as the occurrence of perfect transparency of barriers at normal incidence. Therefore, this peculiar phenomenon would lead to undesired charge leakage in graphene-based devices. Here I will discuss the scattering of Dirac particles by oscillating sharply-peaked barriers, and show how Klein tunneling can be suppressed.

Detecting active processes from spontaneous oscillations of Ear Hair bundles
Edgar Roldán (UCM)

Ear hair bundles are an ensemble of actin filaments that play a key role in the transduction of the sound in the inner ear: they are able to transform external mechanical stimuli in electric signals that are processed by the brain. It has been observed experimentally that ear hair bundles can oscillate spontaneously in the absence of any external force. These oscillations can be produced in different scenarios. The bundles can oscillate as a consequence of active processes, e.g. driven by the motion of molecular motors, but also because of passive processes like thermal fluctuations of the environment. We are interested in finding a method that allows one to distinguish between oscillations produced by active and passive processes from the statistics of a single time series of the position of the top of the bundle in an spontaneous oscillation.
By measuring the Kullback-Leibler divergence of the probability of observing the trajectory with respect to the probability the time-reversed trajectory, we are able not only to distinguish between passive and active oscillations, but also to estimate the minimum energy dissipation that the bundle needs to perform the oscillations, which coincides with the energy dissipation of a single actin motor. We validate our method using simulations of the bundle and also experimental data from bullfrog's inner ear.

Strong anisotropy in surface kinetic roughening: theory and experiments
Edoardo Vivo (UC3M)

It is well known that surfaces subject to growth or erosion processes, as in thin-film production, solid fracture, etc. display a self-affine behavior that can be studied through appropriate observables in real space (roughness and correlation functions) or in Fourier space (power spectral density, PSD), which exhibit power-law behavior whose exponents characterize the long time and large length-scale properties of the system under consideration. Such behavior is usually referred to as Generic Scale Invariance (GSI) or, in the specific context of surface growth dynamics, Kinetic Roughening. Among systems that display GSI, those whose asymptotic properties are anisotropic in space (strong anisotropy, SA) have received a relatively smaller attention, specially in the context of kinetic roughening for two-dimensional surfaces. This is in contrast with their experimental ubiquity, e.g. in the context of thin film production by diverse techniques. In this work, we formulate a SA Ansatz that, albeit equivalent to existing ones borrowed from equilibrium critical phenomena, is more naturally adapted to the type of observables that are measured in experiments on the dynamics of thin films, such as one and two-dimensional height structure factors. We test our Ansatz on a paradigmatic nonlinear stochastic equation displaying strong anisotropy like the Hwa-Kardar equation [1,2], that was initially proposed to describe the interface dynamics of running sand piles. We moreover validate this hypothesis against experimental data from surface nanopatterning of silicon targets by ion-beam sputtering[3].
Additionally, using Dynamic Renormalization Group analysis and direct numerical simulations, we study from a theoretical point of view the appearance of strong anisotropy in nonlinear stochastic equations, both with conserved and non conserved dynamics[4]. Our preliminary conclusions suggest that, in order to take place, asymptotic SA requires special (non-generic) conditions from the shape of the dynamical equation.
[1] T. Hwa and M. Kardar, Phys. Rev. Lett. **62**, 1813 (1989).
[2] E. Vivo, M. Nicoli, and R. Cuerno, Phys. Rev. E **86**, 051611 (2012).
[3] E. Vivo, M. Nicoli, M. Engler, T. Michely, L Vázquez, and R Cuerno, Phys. Rev. B **86**, 245427 (2012).
[4] E. Vivo, M. Nicoli, and R. Cuerno, in preparation.

Capillary Emptying and Short-Range Wetting
Carlos Rascón (UC3M)

Phase transitions of inhomogeneous fluids such as wetting and capillary-condensation that occur when a fluid is confined near a substrate or in parallel-plate geometries have received enormous attention over the last few decades. In most theoretical

studies of these transitions the influence of a gravitational field is either considered secondary or, more often, completely neglected. However, it is clear that gravity plays a central role in many practical situations and, in combination with the confinement, induces further interfacial behaviour. Consider, for example, a large volume of a non-volatile liquid in a tall vertical capillary-slit or cylindrical pore which is capped at its bottom. What happens to the liquid when the capillary is slowly turned to the horizontal? Common experience tells us that the liquid will escape from the open end if the capillary is wide, as when water drains from a tipped glass, but will remain trapped if it is sufficiently narrow such as a drinking straw. It is somewhat surprising to find that this rather basic aspect of capillarity has not been investigated in depth. We show here some theoretical and experimental results of this phenomenon, and point out that this common phenomena is analogous to an interfacial unbinding phase transition involving the meniscus shape and reveals an unexpected connection between capillary-condensation and the theory of wetting transitions [1].

[1] A.O. Parry, C. Rascón, E.A.G. Jamie, D.G.A.L. Aarts, Phys. Rev. Lett. **108**, 246101 (2012)

Bloch oscillations of two electrons interacting by the Coulomb potential

Antonio Rodríguez (UPM)

We study two interacting electrons in a lattice potential subject to an external electrical field. Within the semiclassical approximation, we find regimes of different regimes, depending the system parameters and on the initial conditions:

i Self-trapping Bloch oscillations

ii Unbounded asymptotics

iii Frequency shifted individual oscillations

iv "Chaotic" intermediate regime

Temporal Effects in the Growth of Networks

Giulio Cimini (UC3M)

We show that to explain the growth of the citation network by preferential attachment (PA), one has to accept that individual nodes exhibit heterogeneous fitness values that decay with time. While previous PA-based models assumed either heterogeneity or decay in isolation, we propose a simple analytically treatable model that combines these two factors. Depending on the input assumptions, the resulting degree distribution shows an exponential, log-normal or power-law decay, which makes the model an apt candidate for modeling a wide range of real systems.

Formation and maintenance of nitrogen fixing cell patterns in filamentous cyanobacteria
Saúl Ares (CNB)

In the study of the transition between unicellular and multicellular living forms, cyanobacteria forming one-dimensional filaments are important model organisms. The genus Anabaena has received special interest because under nitrogen-limiting conditions, some cells of the filament differentiate into heterocysts, which lose the possibility to divide but are able to fix environmental nitrogen for the colony. These heterocysts form a quasi-regular pattern in the filament, representing a prototype of patterning and morphogenesis in prokaryotes. Recent years have seen advances in the identification of the molecular mechanism regulating this pattern. We use this data to build a theory on heterocyst pattern formation. We find that it is equally important to model genetic regulation and the effects of cell division and filament growth. For the genetic regulation, we explicitly model the dynamics of HetR, PatS and HetN concentrations. Our theory reproduces quantitatively the experimental dynamics of pattern formation and maintenance for wild type and mutants. Notably, the experimentally observed preponderance of even intervals between heterocysts appears as a result of the interplay of the timescales of genetic regulation and cell division and the noise inherent to these processes.

Casimir effect between Topological Insulators
Pablo Rodríguez-López (UPM)

Toplogical Insulators are a new type of material which exhibits unusual electromagnetic properties. In particular, a three dimensional Topological Insulator is characterized by its topological magnetoelectric susceptibility $\theta \neq 0$. As a consequence, its Fresnel coefficients exibits non–diagonal (magnetoelectric) couplings.
We propose the use of Topological Insulators to control the intensity and sign of the Casimir force. In particular, we show how to control the intensity and sign of the Casimir force (from attractive to repulsive) by tuning the topological magnetoelectric susceptibility of the Topological Insulators. We also show how to obtain a stable equilibrium distance in this system, something forbiden for usual dielectrics.
In our opinion, Topological Insulators can be used to avoid stiction phenomena, to observe ”quantum levitation” in vacuum and to control the intensity and sign of the Casimir force.

Intrinsic noise on Fisher fronts
Svetozar Nesic (UC3M)

The Fisher-Kolmogorov equation is widely used to model systems in biology. It describes reaction diffusion processes in which one (stable) state (usually population) diffuses into another (unstable) one, inducing a travelling wave solution (front). This has a shape that doesn't change in time and travels at a certain velocity. Unfortunately, the continuum equation does not describe properly a real system where the population is finite and it was shown that it could be overcome just adding a certain noise term. There are many interesting results on stochastic Fisher-Kolmogorov equation, duality with real systems and influence of the noise onto velocity of the front. However, due to the numerical and computational difficulties to simulate the equation, it was poorly studied in two dimensions. Namely, the same effect that affects velocity in 1d, makes the 2d front roughen. In the talk I will present the study we have done on the surface growth of equipotential curves (where number of particles is constant) that describe the dynamics of a travelling front of the two dimensional stochastic Fisher-Kolmogorov equation. Our aim was to classify and explain the universality class these fronts belong to and to check the influence that intrinsic noise has on such kind of fronts. We found that the fluctuations of a number of particles where the population is still really small propagate back along the front in time. This effect influences the dynamic of the front providing the same universality class for all equipotential curves along the front. In this case we got that the curves belong to unidimensional KPZ universality class.

Ripple dynamics driven by stress induced solid flow
Ana Moreno (UPC)

Ion Beam Sputtering (IBS) is a well-known technique that has proved useful to produce ordered structures at the nanometer scale. Recently, some discrepancies have been found between theory and experiments, being the so-called ion induced solid flow (or hydrodynamical) theory a good candidate to account for those discrepancies. Here, we generalize this theory in several ways and derive the effective nonlinear continuum equations that describe the temporal evolution of the crystalline and amorphous interfaces. Additionally, we determine the relevant parameters leading to the appearance of patterns and their propagation velocity and analyze its connection with the bulk or surface damage effects. These results allow us to identify the non-trivial role of the amorphous-crystalline interface in the formation and propagation of the pattern. Finally, we discuss some features of the theory regarding to the non-linear stages of the dynamics.

Confirmed attendees

Saúl Ares	Ricardo Brito	Jose A. Capitán
Mario Castro	Pablo Catalán	Giulio Cimini
Sara Cuenda	Rodolfo Cuerno	Jose Cuesta
Elena Díaz	Luis Dinís	Francisco Domínguez-Adame
Clemente Fernández	Andrea Giannini	Clara González-Santander
Yuri Martínez	Ana Moreno	Esteban Moro
Javier Munárriz	Javier Muñoz	Svetosar Nesic
Juan M. Parrondo	Ignacio Pascual	Carlos Rascón
Antonio Rodríguez	Pablo Rodríguez	Edgar Roldán
Angel Sánchez	Silvia Santalla	Rafael Vida
Edoardo Vivo		