REVISTA CUBANA DE FÍSICA
vol. 29, No. 1E (Ago. 2012)

COVER: Group photo of the participants in "Complex Matter Physics: materials, dynamics and patterns" (March*COM*eeting'12) celebrated in Havana from March 6 to 9, 2012. The picture was taken at the entrance of the University of Havana on March 8, 2012 (Photo: O. Ramos)

REVISTA CUBANA DE FÍSICA IS A SPECIAL PUBLICATION OF THE CUBAN PHYSICAL SOCIETY

COORDINATES

OPINION

CONTRIBUTIONS

TRUE COMPLEXITY

For some, a meeting on Complexity is like a big sack where can you put whatever you like. Eventually that approach results in a disjoint collection of subjects, were the only common feature is that each author has conveniently sprinkled some of the "magic keywords" to his/her talk or poster, such as "emergent phenomena", "strange attractor" or "self-organization".

We did our best to circumvent that risk in "Complex Matter Physics: materials, dynamics and patterns" (March*COM*eeting'12), celebrated in Havana from March 6 to 9, 2012.

Indeed, the papers presented at the meeting shared important aspects beyond the use of some "magic keywords". In addition to the aim to quantify and model phenomena using mathematical and computational tools, most subjects approached are strongly nonlinear, and contain many degrees of freedom, and the majority of the papers presented deal with applying the notions of unifying complexity to interconnected physical phenomena occurring in materials.

It is fair to say that March*COM*eeting'12 was possible due to the extraordinary support of the Centre for Advanced Study at the Norwegian Academy of Sciences and Letters (CAS) under the project "Complex Matter Science", headed by T. H. Johansen, and also to the contribution of the "Abdus Salam" International Centre for Theoretical Physics (ICTP). The Physics Faculty and the IMRE (University of Havana), as well as the Cuban Physical Society, should be also thanked for their support.

But the key element for the celebration of the meeting was the enthusiastic will to go ahead with the project of most participants: 60 talks and 33 posters where presented by 78 scientists and students from 11 countries, where Cuba (25), Norway (17), France (15) and the U. S. (8) stood out.

The special number of the Revista Cubana de Física that we are presenting here includes 18 papers submitted by the participants, in addition to an interview given by L. P. Kadanoff, who was assigned the opening talk of the meeting.

March*COM*eeting'12 showed to be an excellent scenario for scientific and human exchange -for one thing, the biggest meeting ever between Norwegian and Cuban physicists. We hope that similar rendezvous will take place in the future.

Ernesto Altshuler
Jon Otto Fossum
Editors

A CONVERSATION WITH LEO P. KADANOFF

BY E. ALTSHULER

Well known physicist Leo P. Kadanoff (James Frank Institute, University of Chicago) had an active participation at March*COM*eeting'12: he gave the opening lecture, and also headed the Committee for the selection of the Best Poster. In the short conversation below, we find his opinions on different aspects of contemporary Physics, from "grand unification efforts", to Physics in Cuba.

E. A. Some claim that we are near to reach the "Theory of everything" in Physics -based on the unification of all forces. The recent (possible) discovery of the Higgs boson seems like an important new piece in the jigsaw. After completing it, our job might be just to understand the details of "non-essential" phenomena -so to speak. Do you think we will actually reach a "Theory of everything"? Should the "leftover phenomena" be regarded as less essential to Physics?

L. K. *In the usual discussions, the "theory of everything" means a theory narrowly aimed at unifying our understanding of gravity and the quantum theory of particles and fields. Such an increased understanding will affect only few small parts of science, especially particle physics and cosmology, and perhaps some additional parts of astronomy. Such a discovery would leave most scientific investigations unaltered in intellectual interest, impact, and value. We do not know if this kind of unification is possible and if it would in any way change our view of the world.*

E. A. One may think that the aim of Physics is to provide quantitative descriptions of natural phenomena -regardless their nature. Under that wide-scoped definition, to what extent Chemistry and Biology are being "engulfed" by Physics these days?

L. K. *I work in an institute that contains both physicists and chemists. They have very different views of the natural world, and aim at very different outcomes. Typically, the chemist is impressed by the richness and variety of nature. His or her work is aimed at discovering differences between the behaviors of different things (usually molecules) and understanding these differences. Physicists emphasize the unity of nature. They (we) typically look for similarities among different things, and try to explain how these similarities arise.*

I see biology as being in an unsettled state. Some Governments and big businesses have heavily supported molecular biology in the hope and expectation that it would have an immense and profitable impact upon human disease. However, the impact has been smaller than expected. Many important processes occur not at a molecular scale, but at a considerably larger scale. Neglected subjects like organism biology and environmental biology have begun to move to the fore. All of these subjects can make occasional use of the kinds of unifying perspectives that can be supplied by the methods of physics. Often they need math knowledge. Very often all of biology needs sophisticated instrumentation and sophisticated understanding of how the instrumentation works. These things can come into biology through the work of physicists. However, biology must come to its own view of nature, distinct from that of physics or chemistry, and beyond that of legislators and drug companies. This is happening slowly.

E. A. As in many human endeavors, attractive labels are used to identify some areas of research as extremely new and "hot" -sometimes the label is well justified, sometimes not so well justified, I'd say. What do you think about the use of "Complexity" as a "trademark" in Science? What about the use of the prefix "nano"…?

L. K. *Words can be traps.*

To say that one works on "complexity" might mean that one is working on the generation of general laws which might apply quite broadly to many complex systems. That can be dangerous because such laws might not exist, or because useful laws might be hard to find. It might be better to say that one works on geothermal turbulence, or the structure of clays, or the walls of biological cells. In each of these areas, there are important discoveries to be made and specific phenomena to be explained.

"Nano" is another trap. There are many interesting things in chemistry, biology, and physics that occur on the scale of nanometers. Very few things are interesting mainly because they occur at nanoscales. A scientist can only go a small way toward justifying his/her work by saying it is "nano". The next step is the important one. Why is it interesting? For illuminating some natural behavior? For constructing some practical device? Why? "Nano" is hardly enough.

E. A. I feel that research in "Complexity" has been liberating for some experimental physicists -like me- due to the fact that, thanks to computers, one can find new Physics in simple, inexpensive experiments. In your opinion, to what extent the field of "Complexity" should be used as a "lifesaver" for experimental Physics in developing countries?

L. K. *Computers are liberating, but they are also dangerous.*

My grandchildren tend to use computers as a replacement for contact with the world. It is particularly important for the Latin world that there be a clear and always-present contact between things that happen in the world and things that are seen in our lab computers. The experimentalist who uses a computer to control and experiment is not too exposed to this danger. The simulator who tries to represent something in nature by a computer program is however very exposed to the danger that he/she might lose contact with the real world of experiment.

E. A. After having participated in a couple of scientific Physics events in Havana during the last two of weeks, what's your impression about Physics in Cuba?

L. K. *I was very impressed by the high quality of physics research in Cuba. There are so many people with good ideas!*

E. A. Cuban physicists tend to publish their finest scientific results in well known, high-impact scientific journals, instead of doing it in the Revista Cubana de Física (RCF) -a natural consequence of the highly competitive nature of science nowadays. What strategy would you suggest to increase the scientific level of the papers published in the RCF?

L. K. *Your scholars would like to be known in the rest of the world. This is natural. Publications in high impact journals are a good way to receiving a bit of recognition from abroad.*

However, recognition from the home country is also a good thing. I would suggest that RCF makes a big fuss about the one or two or five best papers published in a given year.

This fuss might take the form of a few pesos, plus a big certificate, plus a chance to present at a local physical society meeting.

Leo Kadanoff, as president of the selection committee for the Best Poster of March*COM*eeting'12, congratulates A. Hernández for the First Prize, with the poster entitled "A rheological model based on nonlocal relations between shear stress and velocity gradients for complex fluids". The work was made in collaboration with Prof. O. Sotolongo ("Henri Poincarè" Group of Complex Systems, Physics Faculty, University of Havana). In the picture, with a white shirt, organizer J. O. Fossum (Physics Department, Norwegian University of Science and Technology), reads the award act. The scene took place at "Ambos Mundos" hotel, Havana, on March 7, 2012. (Photo: O. Ramos)

EXOTIC BEHAVIOR OF HEXAGONS IN FARADAY WAVES

COMPORTAMIENTO EXÓTICO DE HEXÁGONOS EN ONDAS DE FARADAY

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Three-dimensional numerical simulations of hexagonal patterns in Faraday waves are presented, including details of the velocity field and interface motion. The pattern does not remain hexagonal, but is succeeded by alternation of patterns we call quasi-hexagons and beaded stripes.

Se realizan simulaciones numéricas tridimensionales de patrones hexagonales en ondas de Faraday, incluyendo detalles del campo de velocidades y del movimiento de la intercara. El patrón no permanece hexagonal, sino que es sustituído por patrones que llamaremos cuasi-hexagonales, alternando con patrones de bandas.

PACS: Symmetry breaking flow instabilities, 47.20.Ky; Flow instabilities interfacial, 47.20.Ma; Pattern formation in fluid dynamics 47.54.-r

In 1831, Faraday [1] observed that when a fluid layer is subjected to periodic vertical oscillation of sufficient amplitude, standing waves appear on its surface. These waves may take the form of regular stripes, squares, or hexagons. The experimental observation of more complicated structures, such as quasi-patterns, superlattices or oscillons in the 1990s, has led to a great deal of experimental and theoretical research. Numerical simulations are more recent: the first numerical simulation of Faraday waves was carried out in 2000 for the 2D case by Chen and Wu [2] and by Périnet *et al.* [3] in 2009 for the 3D case .

We summarize our formulation and the numerical methods used to compute the fluid motion; see [3] for a more detailed description. A single-fluid model is used to define the velocity $\boldsymbol{u}$ and pressure p over the entire domain. The viscosity and density are variable, taking the values ν_1, ρ_1 for the denser fluid on the bottom, ν_2, ρ_2 for the lighter fluid at the top and varying abruptly at the surface. The equations we solve are then

$$\partial_t \boldsymbol{u} + (\boldsymbol{u}\cdot\nabla)\boldsymbol{u} = -\frac{1}{\rho}\nabla p + \nu\Delta \boldsymbol{u} \\ -\left[g + a\sin(2\pi f t)\right]\boldsymbol{e}_z + \int \delta(\boldsymbol{x}-\boldsymbol{x}')\sigma\kappa \boldsymbol{n} dV \quad (1)$$

subject to the additional constraints of incompressibility $\nabla\cdot\boldsymbol{u}=0$ and boundary conditions which are periodic in the horizontal directions and no-slip at the vertical boundaries. In (1), the additional gravitational term arises from the transformation to the oscillating reference frame of the container. The last term incorporates surface tension, with σ the surface tension, κ the local curvature, $\boldsymbol{n}$ the vector normal to the surface and pointing from the lower to the upper fluid, and $\boldsymbol{x}$ and $\boldsymbol{x}'$ the positions of points in the domain and on the interface.

We represent the velocity and pressure on a staggered MAC mesh [4] which is fixed and uniform. The moving interface, defined by $z = \zeta(x,y,t)$, is computed by a front-tracking [5]/immersed-boundary [6] method on a semi-Lagrangian triangular mesh which is fixed in the horizontal x and y directions and moves along the vertical direction z. The interface is advected and the density and viscosity fields updated. The capillary force is computed locally on the Lagrangian mesh and then incorporated into the Navier-Stokes equations, which are solved by a projection method. The Poisson problem for the pressure is solved via Biconjugate Gradient Stabilized (BiCGStab) iteration preconditioned by the inverse Laplacian.

The horizontal dimensions of the domain are chosen to accommodate a hexagonal pattern. We take $L_x = 2\lambda_c/\sqrt{3}$ and $L_y = 2\lambda_c$, so that large-scale spatial variations are inaccessible. The simulations were run with a spatial resolution of $N_x \times N_y \times N_z = 58\times100\times180$. Each horizontal rectangle is subdivided into 64 triangles to represent the interface. To validate the spatial discretization, we repeated the simulations with a finer resolution of $N_x \times N_y \times N_z = 75\times125\times225$. Although small quantitative changes were seen, the dynamics remained qualitatively unchanged. The time step is limited by the advective step, taking values varying between T/24 000 and T/4000.

The first detailed spatio-temporal experimental measurements of the interface height of Faraday waves were undertaken by Kityk *et al.* [7, 8]. Their optical technique required the two fluid layers to have the same refractive index, which led them to use fluids of similar viscosities and densities: $\rho_1 = 1346\ kg\ m^{-3}$, $\nu_1 = 5.35 \times 10^{-6}\ m^2\ s^{-1}$, $\rho_2 = 949\ kg\ m^{-3}$, $\nu_1 = 2.11 \times 10^{-5}\ m^2\ s^{-1}$ and surface tension $\sigma = 35\ mN\ m^{-1}$. These parameters, especially the density ratio $\rho_2/\rho_1 = 0.7$, differ markedly from most studies of Faraday waves, which use air above either water or silicone oil and so have $\rho_2/\rho_1 \sim 0.001$. At rest, the heavy and light fluids occupy heights of $h_1 = 1.6\ mm$ and $h_2 = 8.4\ mm$, respectively. The imposed vibration has frequency $f = 12\ Hz$ and the Faraday instability leads to subharmonic standing waves, so that $\zeta(x,y,t)$ oscillates with period $T = 2/f = 0.1666\ s$. Floquet analysis [9] for these parameters yields a critical wavelength of $\lambda_c = 2\pi / k_c = 13.2\ mm \gg h_1$, so that the fluid layer is quite shallow.

The critical acceleration obtained by Floquet analysis is $a_c = 25.8\ ms^{-2} = 2.63g$. For $a \gtrsim a_c$, square patterns are observed experimentally and numerically [3, 7, 8]. The simulations described here were carried out at higher acceleration, $a = 38.0\,ms^{-2} = 3.875g = 1.473\,a_c$, starting from zero velocity and an initial randomly perturbed interface. The simulations produced a hexagonal pattern which oscillates subharmonically [3, 7, 8]. Visualizations of representative velocity fields and of the interface throughout an oscillation period are shown in figures 1 and 2. The patterns and their evolution are far from trigonometric in space and in time. The temporal anharmonicity is a consequence of the high viscosity: a high vibration amplitude a is necessary to overcome the damping and so equation (1) is far from homogeneous in time. The spatial anharmonicity is due in part to the fact that the hexagonal pattern succeeds the squares which appear at onset.

After about 10 subharmonic periods, the hexagonal symmetry is broken and the pattern is replaced, first by another pattern we call beaded stripes, and then by alternation between patterns we call quasi-hexagons and nonsymmetric beaded stripes. Figure 3 shows the time evolution of the instantaneous maximum height $\max_{x,y} \zeta(x,y,t)$ and its envelope $\max_{x,y,[t,t+T]} \zeta(x,y,t)$. Surrounding the time-evolution plot are contour plots of the instantaneous interface height at representative times over one subharmonic cycle, i.e. at times $t_i + jT/4$ for $j = 0,\ldots,3$. The maximum height is strongly correlated with the flow pattern. Since the spatial average of the height remains constant, its maximum measures the spatial variation of the interface. Hexagons (t_1) have the highest peaks, followed by quasi-hexagons (t_3, t_5), and then by beaded stripes (t_2, t_4, t_6). The hexagonal patterns are invariant under the usual symmetry operations of rotation by $\pi/3$ and reflection. The beaded striped patterns are instead invariant under the two reflections:

$$\zeta(x,y) = \zeta(x, n\lambda_c - y) \tag{2a}$$

$$\zeta(x,y) = \zeta(m\lambda_c / \sqrt{3} + \tilde{x}_0 - x, y + n\lambda_c) \tag{2b}$$

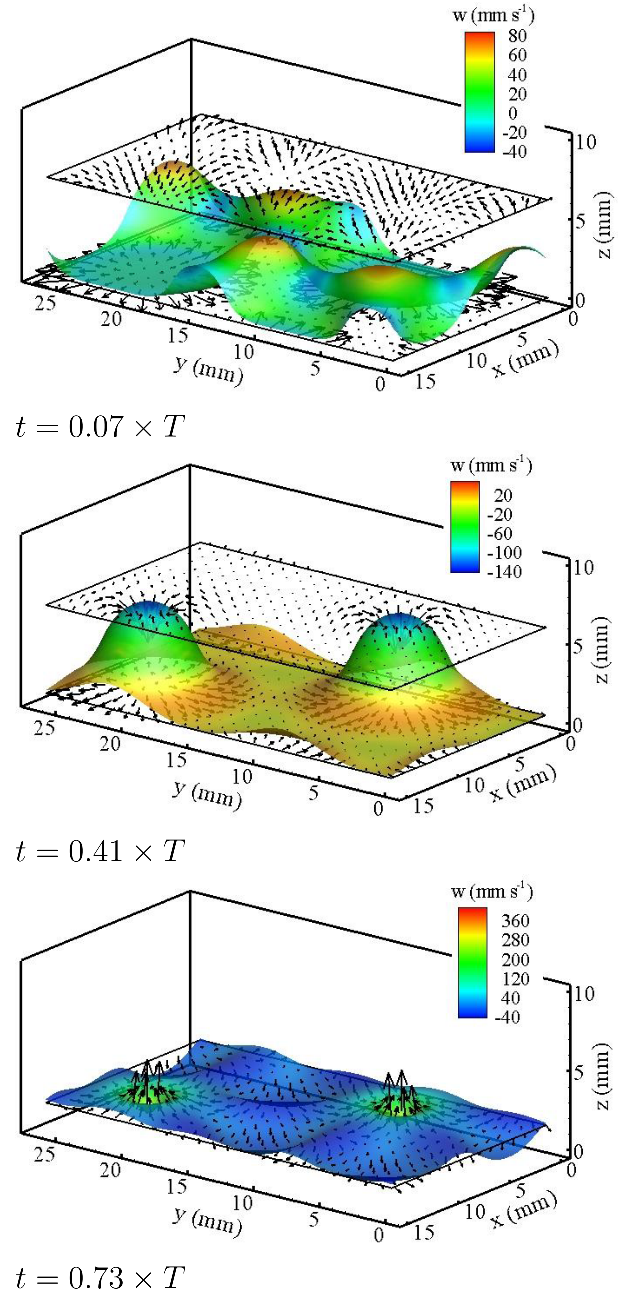

Figure 1: Velocity fields associated with hexagonal patterns.

The quasi-hexagons and nonsymmetric beaded stripes have no exact symmetries but they obey the spatio-temporal symmetry

$$\zeta(x,y,t_{5,6}) = \zeta(m\lambda_c / \sqrt{3} + x_0 - x, y + y_0, t_{3,4} + T/2) \tag{3}$$

That is, the quasi-hexagonal pattern at t_3 is related by a spatial shift-and-reflect operation to that at $t_5 + T/2$ and similarly for the beaded striped patterns at t_4 and t_6. In (2)-(3), $\tilde{x}_0$, x_0 and y_0 are spatial phases whose values depend on details of the initial condition.

The long-time behavior seen in figure 3 could consist of trajectories connecting quasi-hexagonal and beaded striped patterns of each of two phases, i.e. a heteroclinic cycle. An investigation of this hypothesis is currently underway.