1 Evolution of scientific activities

- 1979-1982 Quantum Optics.
- 1980-2005 Applied Optics and instrumentation
- 1982-1990 Transition order-chaos in non-linear systems, especially in fluids.
- 1990-2001 Fluid turbulence.
- 1997-2000 Solid Friction
- 1995-2000 Crack dynamics
- 1996-2009 Crack predictions and precursors.
- 1998-2010 Aging of Amorphous Materials.
- 1998-2010 Statistical properties of out of equilibrium systems.

2 10-Year-Track-Record

In 1998 S.C. begun to reduce his activities in turbulence increasing his research effort in new directions of non-linear and statistical physics. Between 2000-2006 the administrative charges related to his positions of Laboratory Director and of member of the CNRS National Committee forced to stop completely his research on hydrodynamics on which he worked for about 20 years and which remains among his interests. Thus he mainly worked on crack prediction in heterogeneous materials, aging of amorphous materials and mainly on the statistical properties of out of equilibrium stochastic systems. In all of these subjects he got several results, which had a good impact in the community especially in what concerns the experimental application of the Fluctuation Theorem. S.C. has been invited to give a plenary talk on this subject at the next STATPHYS conference in Australia.

Scientific production since 1999

- The S.C. published 68 articles in international journals
- since 1999 (h index= 21, Total citations 1307 and 836 excluding self citations).
- 54 invited talks in international workshops and schools.

Description of the main results obtained since 1999

We will rapidly describe the achievements of different subjects giving more emphasis to the last one which is related with this proposal. We do not discuss the papers, published in this period, which correspond to results obtained before 1999, mainly in hydrodynamics and geophysics.

Crack prediction in heterogeneous materials

This is an experimental and theoretical activity where we performed experiments to test model of slow crack propagation and formation. The main question is whether thermal activation processes can explain the slow crack propagation and the failure of macroscopic sample. Performing experiments in brittle heterogeneous materials and plastic materials we were able to distinguish between the thermal activated component with respect to delays produced by the material visco-elastic properties. This activity benefitted of 4 contracts. 15 papers have been published on this subject (total citation 85). The two most cited are:

- Subcritical statistics in rupture of fibrous materials: Experiments and model. S. Santucci, L. Vanel, S. Ciliberto, Phys. Rev. Lett. 93, 095505 (2004)

- Thermal activation of rupture and slow crack growth in a model of homogeneous brittle materials S. Santucci, L. Vanel, A. Guarino, R. Scorretti, S. Ciliberto, Eur. Phys. Lett. 62, 320 (2003).

Aging of amorphous materials

This activity, which is still running, started in 1998 with PhD thesis of L. Bellon. The goal was the study the statistical properties of systems that are weakly but durably out of equilibrium. We have studied these problems in polymers and gels. In polymers mainly macroscopic sample have been used, whereas in gels we used either macroscopic sample or microscopic colloids particles to probe the local rheology. We got results on the memory effects of a polymers and their comparisons with spin glasses. We have performed several experiment to measure the dielectric noise of polymers and gels during the aging phase. We were interested in studying the violation of the fluctuation dissipation theorem (FDT) in these out of equilibrium systems. In this field we were among the first in trying these difficult measurements and our papers had a good impact in the community.

This research pushed the PI's team in designing and developing new instruments or improving existing ones, among these instruments we may quote. A new interferometer, a zero applied stress rheometer, a new AFM design a very stable optical tweezers and efficient noise subtraction techniques.

13 papers (including the instrumental ones) have been published on this subject and they got more than 300 citations. Two contracts have been obtained on these subjects related to aging.

Many questions are still open and in order to give new insight into this problem of the violation of FDT two years ago the S.C. developed a new research direction which has been inspired by a series of theoretical works. This was the study of the relaxation at the critical point of a second order phase transition, which shares a lot of features with material aging. To study this problem we have mounted an experiment on the FrÃĹederickzs transition in liquid crystals. The result on the FDT violation on this system has been recently published in Phys. Rev. Lett. 102, 130601 (2009). This experiment is very ineteresting but it is difficult to improve our comparison with the theory, because only one variable can be measured. Therefore one has to go to other systems, such as the one proposed in this project.

The three most cited papers on aging in polymer and gels are:

- Intermittency in ageing, L. Buisson, L. Bellon, S. Cililiberto, Journal of Physics : Cond. Mat. 15 (11), 1163 (2003)
- Memory in the aging of a polymer glass, L. Bellon, S. Ciliberto, C. Laroche, Europhysics Letters 51, 551 (2000)
- Violation of the fluctuation dissipation relation during the formation of a collidal glass. L. Bellon, S. Ciliberto, C. Laroche, Europhysics Letters, 53, 511 (2001)

Fluctuations of the injected and dissipated power in out of equilibrium systems

The largest part of this research is related to the study of the experimental applications of the Fluctuations Theorem(FT), which is an important results giving a relationship between the probabilities of observing a negative and a positive value of the entropy production rate in an out of equilibrium system. Making experiments on this subject is useful to test the hypothesis of the theorem an its applicability to parctical cases. In 1998 the S.C. was the first to show that this is possible experimentally (Journal de Physique IV,8,215 (1998)). This paper had certainly several limits but it really pushed towards these experimental studies of FT. In this last year we worked on several experiments in electrical circuits, in optical tweezers and in mechanical oscillators, where we tested several theoretical idea concerning FT for work, heat and entropy. We also developed simple models that allow the explanation of the experimental observations.

Besides this work on FT we have also studied another interesting problem, in collaboration with P. Gaspard of ULB(Bruxelles). We performed several experiments to show that it is possible to measure the entropy production only studying the time asymmetries of non-equilibrium fluctuations. The results of this activity in out of equilibrium systems has been published in 12 papers which have 253 citations.

The four most cited on stochastic systems are:

- Nonequilibrium fluctuations in a resistor, N. Garnier, S. Ciliberto, Phys. Rev. E. Phys. Rev. E 71, 060101 (2005)
- An experimental test of the Jarzynski equality in a mechanical experiment F. Douarche, S. Ciliberto, A. Petrosyan and I. Rabbiosi, Europhysics Letters, 70, 5, 593 (2005).
- Work Fluctuation Theorems for Harmonic Oscillators F. Douarche, S. Joubaud, N. B. Garnier, A. Petrosyan, and S. Ciliberto Phys. Rev. Lett. 97, 140603 (2006)
- Entropy production and time asymmetry in nonequilibrium fluctuations, D. Andrieux P. Gaspard, S. Ciliberto, N. Garnier, S. Joubaud, et A. Petrosyan, Phys. Rev. Lett. 98, 150601 (2007)

2.0.1 Information and thermodynamics

Within the context of fluctuating thermodynamics and out of equilibrium physics he became interested in the connections between information and thermodynamics. Specifically in collaboration of A. Petrosyan and others he performed an experimental test of the Landauer principle, which predicts the minimum amount of work necessary to produce a bit of information. This work shows for the first time that the Landauer limit can reached experimentally.

- Experimental verification of LandauerâĂŹs principle linking information and thermodynamics, A. Bérut1, A. Arakelyan, A. Petrosyan, S. Ciliberto, R. Dillenschneider, E. Lutz, Nature 483,187 (2012).