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Tribute to an exemplary man: Yves Couder

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Yves Couder was trained as a physicist at the end of the sixties in Paris, Orsay. At that time, Solid State Physics was attracting most of the brilliant researchers, and Yves Couder naturally integrated into the Groupe de Physique des Solides at the Ecole Normale Supérieure. There was, at that time, a gap in the electromagnetic waves available in the laboratory. This gap, between the far infrared and the microwave domains, was filled by the introduction of a new type of sources: the carcinotrons that generated waves with wavelengths in the sub-millimetre range. This opened new possibilities for solid state physics and Yves Couder contributed to develop this new tool to investigate cyclotron resonance, the Josephson effect, as well as spin resonance at those frequencies.

But the field of Solid State Physics was becoming progressively less rich in surprises and new effects, and this was not in the taste of Yves Couder who, like some in his generation with the same background, decided to move to a new field where he could exercise his taste for simple but demonstrative experiments, with the great advantage compared to Solid State Physics that the phenomena can be seen by eye rather than through complicated apparatus and/or conceptual models: that was Fluid Mechanics and Nonlinear Physics.

Then followed a series of fascinating experiments, all characterized by the lightness of their set-up sometimes called "table-top experiments" or "physique en espadrille" (in french, P. Huerre), but also characterized by the profoundness of the effects they were dealing with. Below is an attempt to classify the variety of subjects covered by Yves Couder:

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- *Vortex dynamics in 2D, and concentrated vortical structures in 3D*: Yves Couder introduced the idea that soap films can be used to study 2D turbulence and 2D vortex dynamics. This permitted him to obtain experimental evidence of the inverse energy cascade, as well as the observations of the spontaneous formation of vortex dipoles in 2D turbulence. A groundbreaking experiment introduced a new type of stirring to obtain highly turbulent flows in a confined cell. This configuration nicknamed “the French washing machine” has been widely used since, and provided the first experimental observation of high vorticity filaments in a turbulent flow.
- *Non linear dynamics and Saffman–Taylor fingers*: The emergence of patterns and their non-linear dynamics have been investigated by Yves Couder in many experiments. One of his major contributions is the discovery of the singular role played by small perturbations at the forehead in the selection of Saffman–Taylor’s finger width, the critical role of capillarity in tip-splitting events, opening fruitful analogies with dendritic growth and Diffusion Limited Aggregation.
- *Phyllotaxis, Morphogenesis*: The spiral organization of plants have a remarkable relation to the Fibonacci sequence and the golden ratio. Yves Couder used an elegant fluid dynamics experiment to demonstrate that it results from self organization in a simple dynamical system. This was the key to a global interpretation: the system tends towards irrational numbers because of its geometrical trend to avoid rational patterns. More generally, Yves Couder has questioned the role of mechanics in morphogenesis, which has motivated a number of researches to better understand the role of mechanical stresses in the growth of living tissues, especially in plants.
- *Singularities in Mechanics*: Any applied constraint that tends to change the gaussian curvature of a solid plate leads to a concentration of the stress in localized areas like folds or d.cones, while the gaussian curvature remains unchanged elsewhere. Yves Couder devised experiments that are among the first quantitative investigation of this effect.
- *Wave-particle duality in macroscopic Fluid Mechanics*: Having demonstrated that a droplet can bounce on a vertically vibrated liquid interface and that it naturally couples with the surface wave it excites, Yves Couder has shown that the droplet can then self-propel. This “wave-particle” coupling at the macroscopic scale has allowed him to re-visit the traditional phenomenology of quantum mechanics (double slit experiment, tunnel effect, quantization of orbits etc,...), reviving the “pilot wave theory” of Bohm which had been overshadowed by the Copenhagen interpretation of quantum mechanics, the dogma in the field.

Yves Couder’s style in research was unique: it is made of a subtle mixture of curiosity, simplicity, pertinence, relevance, and elegance, to the point that the expression “à la Couder” is commonly employed for qualifying a nice piece of experimental work made on an original topic. A work where the emphasis is placed on creativity suggested by a profound question, not on the rationalization of a conventional question by systematic techniques. And certainly not for the only purpose of proving a theory; Yves Couder had a high sense of what the experimentalist should be: a questioner of nature, tracking manifestations, effects and analogies, certainly not a second hand servant for theoreticians. This is probably the reason why he was highly praised by them, and had fruitful and renewed collaborations with the best of them.

His style has naturally influenced a number of collaborators and/or ex-students who have now all developed a brilliant independent career, a large number of them having contributed to this special issue of the Comptes Rendus. The reader will find below a tribute to the man and his carrier by Huerre, and a lesson by Fineberg on how a research track emerges from life opportunities.

It is customary to oppose teaching with research although these two aspects of a professor's life may complement and cross-fertilize each other. The papers by Andreotti *et al.* and by Baconnier *et al.* remind us that Yves Couder has also been strongly involved in renewing teaching methods, and has been at the origin of the concept of "Phyexp", namely long experimental projects proposed to students on open questions which have been for some of them, in return, the birthplace of several Yves Couder's research subjects. When teaching at the graduate level, at the *DEA de Physique des Liquides*, a curriculum appreciably loaded with theory, he used to start his class saying: "I will tell you about instabilities, but from an experimentalist point of view".

Yves Couder's work is also characterized by an aesthetics of what a "beautiful experiment" is, as evidenced by the striking pictures illustrating many of his contributions, a quality that reflects his unique sense of observation and his photographer's eye (his father André was a famous optician astronomer), a feature clearly apparent in Chomaz' paper. This issue also incorporates recents developments on topics Yves Couder was familiar with, namely instabilities, nonlinear fluid mechanics, patterns (Bach *et al.*, Fauve, Rabaud & Moisy) and turbulence (Brachet, Cadot *et al.*, Xu *et al.*).

Bouncing droplets, the possible analogy with quantum mechanics and the status of memory in physical systems have been a source of inspiration for many as attested by Pomeau, Libchaber & Tlusty, Dagan & Bush, Barnes *et al.* and Devauchelle *et al.*

The coupling between growth and form in reference to Darcy Thomson's famous book has been a recurrent obsession of Yves Couder, and the papers by Ben Amar & Dervaux, Siéfert & Roman, Hakim, Pauchard and Douady *et al.* show how mechanical analogies may be fruitful to understand some persistent trends in nature. The link with biology and the role of mechanics in plants growth, where Yves Couder was also a pioneer, are discussed by Traas & Hamand and Peaucelle.

At a time when it is commonplace to hear that Physics is a dead subject, that computers will pave the way of an artificial future, Yves Couder's abiding message is more interesting: Mechanics, from fluids to solids, remains a vivid subject, full of unpredictable surprises, and in deep contact with the foundations of our understanding of the laws of nature. In this quest, the experimental work, the deep and acute look at phenomena remains essential as a source of surprise and fundamental questioning.

We thank all the contributors to this special issue for making it so rich and diverse, at the image of Yves' career, and we hope that his example will remind us that the motto should not be "publish or perish" nor "ever more contracts", but rather "publish less and better" and "take the time to be surprised", the real recipe to withstand the test of time.