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Tribute to an exemplary man: Yves Couder

Hommage to the man and his career

Yves Couder (1941–2019): A life in search of the beauty of fluid motion

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Abstract. In this article, I briefly discuss the remarkable scientific accomplishments of Yves Couder, their impact in the fluid dynamics community worldwide and his unique personality. It is a personal tribute to a friend and a colleague I have known for the past 35 years.

Keywords. Soap films, Turbulence, Fingering, Morphogenesis, Drop dynamics.

Yves Couder passed away at age 78 on April 2, 2019 in Paris, surrounded by his wife Lorna and their two children Jeanne and Julien. Many of his friends and colleagues attended the memorial and burial ceremonies held on April 8, 2019.

He was Professor of Physics at the Denis Diderot University in Paris and a member of the *Académie des Sciences*.

After completing his doctorate in physics at the University of Paris in 1965, Yves started working at *Ecole normale supérieure* where he created and developed a talented and thriving research team. In 1985, he also became Professor of Physics at the Paris Denis Diderot University where, as of 2006, his research activities moved within the *Matière et Systèmes Complexes (Matter and Complex Systems)* laboratory. He played a pivotal role in the foundation and establishment of this new lab.

Yves Couder's research achievements in Fluid Dynamics are simply stellar: he has made pace-setting and truly seminal contributions in several important areas of the field by conceiving deceptively simple experiments. Here are some of his most striking accomplishments in Fluid Physics and in closely connected areas.

Soap films, dynamics of vortices and two-dimensional turbulence. Yves Couder and colleagues [1, 2] were the first to introduce soap films as an original setting to study the dynamics of vortices and the properties of two-dimensional turbulence. In particular he was able to observe and characterize the inverse energy cascade predicted by the theory of two-dimensional turbulence. This very productive analogy subsequently led to the development of other soap film experiments in several groups in the USA and Europe.

Figure 1. Yves Couder and Stéphane Perrard, 2011.

Three-dimensional turbulence and vortex filaments. Yves Couder and colleagues [3] were also the first to detect and characterize intense vortex filaments in three-dimensional turbulence. They showed that such filaments, referred to as the *sinews of turbulence* by Keith Moffatt, are responsible for the production of low-pressure bursts in the so-called *French washing machine* experiment.

Saffman-Taylor fingering. This phenomenon refers to the formation of fingers at the interface between two fluids when a more viscous fluid is displaced by another less viscous fluid. Yves [4] demonstrated that the application of singular perturbations at the tip of the finger is sufficient to influence the selection process that determines the finger configuration.

Ferromagnetic drops, morphogenesis and the growth of plants. The spiral patterns displayed by plants may be explained by resorting to the properties of Fibonacci sequences and the Golden Mean. Yves has confirmed these features by studying in detail the spiral patterns formed by the arrangement of seeds in the central bud of sunflowers [5, 6]. Here again he proposed a striking analogy between this process and pattern formation in a collection of ferromagnetic drops. This fluid experiment led to a global interpretation of the observed patterns: the system of drops tends to a configuration based on irrational numbers since, during the pattern formation process, it is observed to avoid rational numbers.

Particle-wave duality in drop dynamics. In his last years (Figures 1 and 2), Yves Couder was engaged in a comprehensive investigation of the dynamics of drops that bounce on a liquid interface subjected to periodic vertical oscillations (Faraday experiment). This set-up revealed the existence of a dynamic coupling between the vertical motion of the bouncing drop and the gravity

Figure 2. Yves Couder and Emmanuel Fort, 2011.

wave field which it generates [7, 8]. The study of this phenomenon has led to fascinating macroscopic analogs of G.I. Taylor's single-photon experiment and de Broglie's electron diffraction experiment [9]. Chaotic régimes were more recently identified [10] and Yves' pioneering studies have triggered further important research in the USA.

John Bush, Professeur of Mathematics at MIT, whose recent work has been inspired by Couder's, states: "In demonstrating the possibility of both observing and understanding this phenomenon on a macroscopic scale, Couder's experiments invite us to reconsider the philosophical foundations of quantum mechanics. What better role for fluid mechanics than questioning the foundations of modern physics? What better goal than the prospect of restoring determinism and realism to science ? Indeed it is (one's) hope that hydrodynamic quantum analogue systems, as initiated by (Yves) Couder, will establish fluid mechanics as a subject worthy of representation in modern physics departments worldwide. Couder's research (presently) continues in the pioneering spirit of G.I. Taylor" (John Bush private communication).

During his career, Yves received many distinctions: the Prize of *Institut Français du Pétrole* of the *Académie des Sciences* in 1993, the Gentner-Kastler Prize jointly awarded by the *Deutsche Physikalische Gesellschaft* and the *Société Française de Physique* in 2006, the *Trois Physiciens (Abraham, Bloch et Bruhat)* Prize in 2007. He received in 2012 the EUROMECH Fluid Mechanics Prize of the *European Mechanics Society* with the simple, yet very meaningful citation: *for experiments in fluid mechanics which are novel, elegant, deep and provocative.*

Yves' *creativity* was exceptional and he had a special talent for detecting profound analogies between seemingly very distinct fields. He has had a profound impact on colleagues and young brilliant researchers both in the US and in Europe, who constitute what may rightfully be called an informal Couder school of macroscopic physics.

As the reader of these lines may already know, Yves was the kind of Man one rarely happens to meet during a researcher's career. As far as I am concerned, it was on the occasion of my visit at *Ecole Normale Supérieure* in Paris in 1985 that I had the chance of getting to know him. In those years, he worked with Marc Rabaud and Jean-Marc Chomaz on obtaining strikingly beautiful images of the dynamics of vortices in liquid soap films (see above).

One could not avoid being seduced by the disconcerting, yet deep, *freshness* of his intellect. A few weeks before his passing, as he was severely weakened, I was once more surprised by his corrosive intuition regarding the different types of memory, when he juggled from his experiments on jumping drops (see above) to rebound on his thoughts relative to the distinct forms of memory of the human mind.

This was also obvious in the way he interacted with friends and colleagues. I will never forget his warm voice and the discretely amused twinkles in his eye. When one came to know him better, one would discover a genuine *modesty*. No incongruous pomposity in communicating the results of his own research but rather an immediate opening to address the next relevant and pressing questions! The new developments, although remarkable, would almost be relegated in favour of really new unresolved issues!

Thus, it is on many grounds that Yves was elected to the *Académie des Sciences* in 2013 within the section of *Mechanical and Computational Sciences*. We both used to joke about the coexistence of two distinct communities of researchers in fluid dynamics: physicists and for lack of an equivalent word in English, *mécaniciens*. These two varieties of fluid dynamicists were frequently rivals but they were unanimous in welcoming Yves within the Academy. During our debates regarding the selection of candidates for various prizes, he would focus his attention on the major scientific achievements of the candidates and bypass most biographical aspects in their career, which to him, appeared to be anecdotal. Once again, this was typical of his approach, away from the marked trails and right to the essentials.

Last but not least, on a more personal note, I fondly keep in my mind the lively and lovely dinners at Lorna and Yves' home on *La butte aux cailles* in Paris where one would always have stimulating conversations in a convivial atmosphere.

Yves Couder is sorely missed in our community but for years to come, he will remain a vibrant source of inspiration…

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