Yves Couder

A fluid dynamics wave-particle duality:
from chaotic individual trajectories to probabilistic behaviours

I. The self-propulsion of localised Faraday modes excited by a bouncing droplet

When a fluid is vertically vibrated, its surface can become unstable so that standing waves form on the whole surface. This is the well-known Faraday instability. Below the threshold of this phenomenon the surface is stable but the disturbance due to a droplet bouncing on the interface can be sufficient to trigger a localized mode of Faraday waves. It is observed that the droplet and its associated wave then become spontaneously propagative. They thus form a symbiotic structure that we called a "walker". We will first describe the complex interference pattern exhibited by its wave-field(1). We will show that it results from the superposition of the waves generated in all the points recently visited by the droplet. Its structure thus contains what we called a "wave mediated path-memory". The situation is simple when the walker has a rectilinear motion, but not so simple in all the other situations

II. A macroscopic type of wave-particle duality

We will thus present several experiments in which we addressed one single central question. In the presence of memory, how can the localized and discrete droplet have a common dynamics with the continuous and spatially extended wave? The spatial and temporal non-locality due to path memory generates interesting effects. We investigated, for instance:

- The orbital motion of a walker when the droplet is submitted to a transverse force(2). We will show that in the presence of path memory the measured orbit radius, instead of varying continuously with the force, can only take quantized values.
- The reaction to attempts of spatial confinement. We find that in those situations the trajectory of an individual walker(3) becomes disordered. However statistical analyses show that deterministic mean behaviours are maintained, giving rise to well determined probabilities.

Finally, the limits in which this macroscopic type of wave-particle duality can be compared to the quantum duality will be discussed.

(1) A. Eddi, E. Sultan, J. Moukhtar, E. Fort, M. Rossi, and Y. Couder. *J. Fluid Mech .**674,** 433-464*, (2011).
(2) E. Fort, A. Eddi, A. Boudaoud, J. Moukhtar, and Y. Couder, *PNAS* **107**, 17515-17520, (2010).
(3) Y. Couder & E. Fort, *Phys. Rev. Lett.* **97**, 154101,1-4, (2006).