Slow walkers in a propagating wave field

O. Devauchelle[1], E. Lajeunesse[1], F. James[2], C. Josserand[3] & P.-Y. Lagrée[4]

[1] Institut de Physique du Globe de Paris, F-75238 Paris, France
[2] Institut Denis Poisson, Université d'Orléans, Université de Tours, CNRS UMR 7013, BP 6759, F-45067 Orléans Cedex 2, France
[3] LadHyX, CNRS and École Polytechnique, UMR 7646, IP Paris, 91128 Palaiseau, France
[4] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, F-75005 Paris, France
devauchelle@ipgp.fr

Since Couder et al. [1] noted that a droplet of silicon oil could bounce on a vibrated bath of the same liquid, and roam across the latter's surface in response to the Faraday wave it excites, this wave-particle couple has revealed an ever-increasing variety of odd traits [2,3]. Its strange behavior irresistibly reminds one of quantum systems [4], although the analogy remains debated [5]. As experimenters' developed their ability to handle bouncing droplets, the theoretical models that represent them evolved from low-dimensional, dynamical systems [6] to refined representations of the wave field coupled to the vertical dynamics of the droplet [7]. We propose a hybrid model which combines a simplified wave field, in the form of the Helmholtz equation, with a first-order relaxation in lieu of memory [8]. This model uses the stroboscopic approximation introduced in the early models to guide the particle's horizontal motion. We find that, within this framework, the phase lag between the the droplet's bounces and the surrounding wave controls the appearance of walkers, and their travel across the bath. An unexpected property of this simple model is that it naturally contains propagating waves—as opposed to standing ones, like the Faraday wave. More surprisingly still, the nature of the wave does not affect much the behavior of the walker, suggesting that the bouncing droplet belongs to a broader class of systems, which extends beyond fluid mechanics [9].

Références

1. Y. Couder, S. Protière, E. Fort and A. Boudaoud, *Dynamical phenomena : Walking and orbiting droplets*, Nature, 437, 7056, 208, 2005.
2. S. Protière, A. Boudaoud, and Y. Couder, *Particle–wave association on a fluid interface*, Journal of Fluid Mechanics, 554 :85–108, 2006.
3. Y. Couder and E. Fort, *Single-particle diffraction and interference at a macroscopic scale*, Physical review letters, 97(15) :154101, 2006.
4. J.W.M. Bush, *Quantum mechanics writ large*, Proceedings of the National Academy of Sciences, 107(41) :17455–17456, 2010.
5. A. Andersen ; J. Madsen ; C. Reichelt ; S. R. Ahl ; B. Lautrup ; C. Ellegaard ; M. T. Levinsen ; T. Bohr *Double-slit experiment with single wave-driven particles and its relation to quantum mechanics*, Phys. Rev. E, 92, 1, (013006), (2015)
6. E. Fort, A. Eddi, A. Boudaoud, J. Moukhtar, and Y. Couder, *Path-memory induced quantization of classical orbits*, Proceedings of the National Academy of Sciences, 107(41) :17515–17520, 2010.
7. P.A. Milewski, C.A. Galeano-Rios, A. Nachbin, and J.W.M. Bush, *Faraday pilot-wave dynamics : modelling and computation*, Journal of Fluid Mechanics, 778 :361–388, 2015.
8. O. Devauchelle, E. Lajeunesse, F. James, C. Josserand, P.-Y. Lagrée *Walkers in a wave field with memory*, Comptes Rendus Mécanique, 348, 6-7, 591-611, 2020.
9. Y. Dagan, J. W. M. Bush*Hydrodynamic quantum field theory : the free particle* Comptes Rendus Mécanique, 348, 6-7, 555-571, 2020.