Exploring single-particle diffraction with a pilot-wave model

Giuseppe Pucci[1,2], Antoine Bellaigue[2], Anand U. Oza[3]

[1] Consiglio Nazionale delle Ricerche - Istituto di Nanotecnologia (CNR-NANOTEC), Via P. Bucci 33C, 87036 Rende, Italy.
[2] Univ Rennes, CNRS, IPR (Institut de Physique de Rennes)—UMR 6251, F-35000 Rennes, France.
[3] Department of Mathematical Sciences & Center for Applied Mathematics and Statistics, New Jersey Institute of Technology, Newark, New Jersey 07102, USA.
giuseppe.pucci@cnr.it

Millimetric liquid droplets can bounce indefinitely on the surface of a vertically vibrating bath of the same liquid [1]. In some regimes, these droplets self-propel on the liquid surface by bouncing on the wave field created by their previous impacts [2]. A series of experiments with these walking droplets have shown a number of quantum-like behaviors [3]. One of the seminal experiments suggested that single-particle diffraction and interference may be obtained when a droplet crosses a single- or double-aperture between submerged barriers [4]. Later experiments with finer control of experimental parameters yielded different conclusions with respect to the seminal experiments [5,6,7], thus reopening the question of the extent of the analogy between walking droplets and quantum particles. Here we use the pilot-wave model developed by Oza et al. [8] to describe walking droplets and explore the diffraction of a two-dimensional, wave-piloted particle by one-dimensional barriers. The statistical distribution of deflection angles is wavelike and generally exhibits multiple peaks (Fig. 1), the number of which depends on the obstacle geometry.

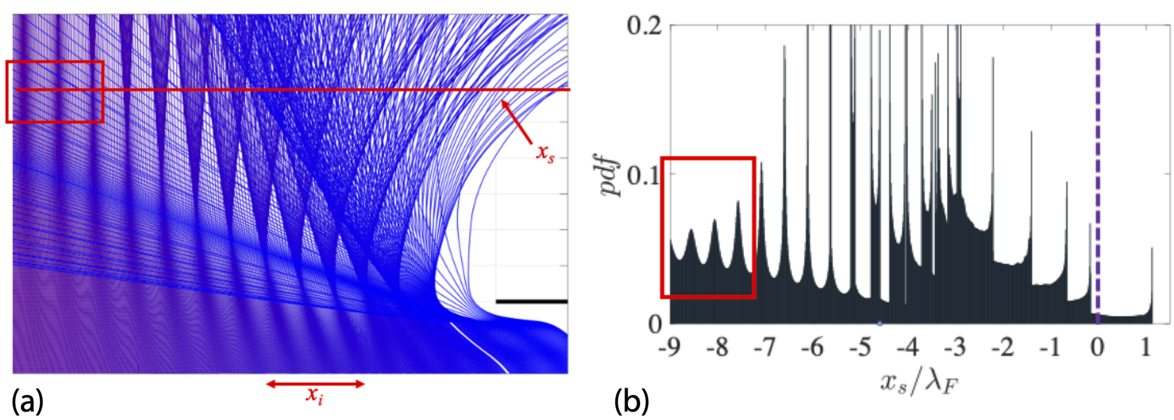

Figure 1. Interaction of an ensemble of wave-piloted particles with an edge (black line in panel (a)). (a) Multiple trajectories of a single droplet with varying impact parameter x_i, with the droplet moving from the bottom of the panel toward the top. (b) Probability distribution function of the droplet impacts on a horizontal screen placed at a distance $3\lambda_F$ above the edge (red line on panel (a)). The wavelength of Faraday waves is denoted by λ_F.

References

1. Y. Couder et al., *Phys. Rev. Lett.*, **94**, 177801, (2005).
2. Y. Couder et al., *Nature*, **437**, 208, (2005).
3. J. W. M. Bush and A. U. Oza, *Rep. Prog. Phys.*, **84**, 017001, (2020).
4. Y. Couder and E. Fort, *Phys. Rev. Lett.*, **97**, 154101, (2006).
5. G. Pucci et al., *J. Fluid Mech.*, **835**, 1136-1156, (2018).
6. M. Rode, J. Madsen and A. Andersen, *Phys. Rev. Fluids*, **4**, 104801, (2019).
7. C. Ellegaard and M. T. Levinsen, *Phys. Rev. E*, **102**, 023115, (2020).
8. A. U. Oza et al., *J. Fluid Mech.*, **737**, 552-570, (2013).