



Københavns Universitet

Comment on Y. Couder and E. Fort

Andersen, Anders ; Madsen, Jacob; Reichelt, Christian; Ahl, Sonja Rosenlund; Lautrup, Benny Elley; Ellegaard, Clive Sigurd; Levinsen, Mogens; Bohr, Tomas

Published in:
arXiv.org: Physics

Publication date:
2014

Document Version
Early version, also known as pre-print

Citation for published version (APA):
Andersen, A., Madsen, J., Reichelt, C., Ahl, S. R., Lautrup, B. E., Ellegaard, C. S., ... Bohr, T. (2014). Comment on Y. Couder and E. Fort: Single-Particle Diffraction and Interference at a Macroscopic Scale; Phys. Rev. Lett. 97, 154101 (2006) . arXiv.org: Physics, 1405.0466v1.

Comment on
Y. Couder and E. Fort:
*Single-Particle Diffraction and Interference at a
Macroscopic Scale*
Phys. Rev. Lett. **97**, 154101 (2006).

Anders Andersen¹, Jacob Madsen¹, Christian Reichelt¹, Sonja Rosenlund Ahl¹,
Benny Lautrup², Clive Ellegaard³, Mogens T. Levinsen³, and Tomas Bohr¹

¹*Department of Physics and Center for Fluid Dynamics,
Technical University of Denmark,
DK-2800 Kgs. Lyngby, Denmark*

²*Niels Bohr International Academy, The Niels Bohr Institute*

³*The Niels Bohr Institute, University of Copenhagen, Denmark*

In a paper from 2006, Couder and Fort [1] describe a version of the famous double slit experiment performed with drops bouncing on a vibrated fluid surface, where interference in the particle statistics is found even though it is possible to determine unambiguously which slit the “walking” drop passes. It is one of the first papers in an impressive series, showing that such walking drops closely resemble de Broglie waves and can reproduce typical quantum phenomena like tunneling and quantized states [2–13]. The double slit experiment is, however, a more stringent test of quantum mechanics, because it relies upon superposition and phase coherence. In the present comment we first point out that the experimental data presented in [1] are not convincing, and secondly we argue that it is not possible in general to capture quantum mechanical results in a system, where the trajectory of the particle is well-defined.

In the double slit experiment [1], 75 drop passages of the slits are recorded (their Fig. 3). This small number is increased by symmetrization, which, however, does not improve the statistics. Submitting the data to a standard χ^2 -test, a fit to a Gaussian distribution is found to be just as good as the fit to the Fraunhofer interference pattern presented in the paper. In addition the blue envelope curve (single slit result) shown in their Fig. 3 is not backed up by data because the single slit results presented in the paper (their Fig. 2) are for slits of different widths than those of their Fig. 3. We have tried to reproduce their results experimentally with our own double slit set-up, but without success.

The walking drops are reminiscent of de Broglie waves. In his later years de Broglie [14] took his wave idea further and imagined that particles could be described as moving singularities in a field, which, in addition to the probabilistic Schrödinger wave function, had a new “physical” component excited locally by the particle - just like what happens in the experiment. We have tried to implement this idea by introducing a source term in the standard Schrödinger equation, i.e., $(i\hbar\partial/\partial t - \hat{H})w(\mathbf{r}, t) = J(\mathbf{r} - \mathbf{R}(t))$ where $\mathbf{R}(t)$ is the position of the particle, and the source term J is a complex function. Due to linearity, it is sufficient to choose the source term equal to a δ -function, i.e., $J(\mathbf{r} - \mathbf{R}(t)) = \delta(\mathbf{r} - \mathbf{R}(t))$. In addition, the particle is guided by the wave according to the standard Madelung-Bohm equa-

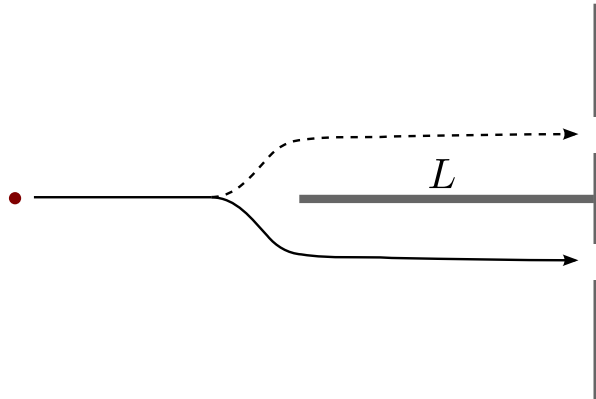


FIG. 1: Double slit experiment with a splitter plate of length L . A particle will have to move on one or the other side of the plate as shown by the two possible trajectories.

tion $\dot{\mathbf{R}}(t) = (\hbar/m) \nabla \Phi(\mathbf{r}, t)|_{\mathbf{r}=\mathbf{R}(t)}$, where Φ is the phase of the complex function w . In the absence of potential energy, our theory indeed leads to free “particles” in the form of singular wave-fields moving with constant velocity and resembling the walking drops.

We now consider a slightly modified version of the double slit experiment, where a “splitter plate” of length L has been inserted symmetrically in between the two slits (Fig. 1). This change would not significantly alter the quantum mechanical description or the interference pattern. A wave packet moving towards the double slit will be diffracted by the edge of the splitter plate and slowly disperse while moving along it. Thus, with the splitter plate it will be weaker when it arrives at the double slit, but the two parts of the wave packet arriving at the slits will still be exactly in phase, thus giving rise to the same kind of interference pattern as without the plate.

For our version of de Broglie like quantum mechanics, this would not be so. The particle reaching the splitter plate would unavoidably have to proceed along one side or the other (Fig. 1). The field at the “chosen” side behaves roughly like our stationary solution for a free particle while it moves towards the slit. The field on the “other” side, however, has basically no source term, since the source is on the chosen side of the splitter plate, and the wave-packet on the other side will therefore slowly disperse. For sufficiently large L , the particle emerging from the slit will thus

only experience an extremely weak influence from the other slit, which would not be able to deflect it, and as $L \rightarrow \infty$ the classical result is recovered: the superposition of the probability distributions for each single slit without interference.

- [1] Y. Couder and E. Fort, Phys. Rev. Lett. **97**, 154101 (2006).
- [2] A. Eddi, E. Fort, F. Moisy, and Y. Couder, Phys. Rev. Lett. **102**, 240401 (2009).
- [3] E. Fort, A. Eddi, A. Boudaoud, J. Moukhtar, and Y. Couder, PNAS **107**, 17515 (2010).
- [4] A. Eddi, E. Sultan, J. Moukhtar, E. Fort, M. Rossi, and Y. Couder, J. Fluid Mech. **674**, 433 (2011).
- [5] A. Eddi, J. Moukhtar, S. Perrard, E. Fort, and Y. Couder, Phys. Rev. Lett. **108**, 264503 (2012).
- [6] D. M. Harris, J. Moukhtar, E. Fort, Y. Couder, and J. W. M. Bush, Phys. Rev. E **88**, 011001(R) (2013).
- [7] J. Moláček and J. W. M. Bush, J. Fluid Mech. **727**, 582 (2013).
- [8] J. Moláček and J. W. M. Bush, J. Fluid Mech. **727**, 612 (2013).
- [9] A. U. Oza, R. R. Rosales, and J. W. M. Bush, J. Fluid Mech. **737**, 552 (2013).
- [10] Ø. Wind-Willassen, J. Moláček, D. M. Harris, and J. W. M. Bush, Phys. Fluids **25**, 082002 (2013).
- [11] D. M. Harris and J. W. M. Bush, J. Fluid Mech. **739**, 444 (2014).
- [12] A. U. Oza, D. M. Harris, R. R. Rosales, and J. W. M. Bush, J. Fluid Mech. **744**, 404 (2014).
- [13] S. Perrard, M. Labousse, M. Miskin, E. Fort, and Y. Couder, Nature Comm. **5**, 3219 (2014).
- [14] L. de Broglie, Ann. Fond. Louis de Broglie **12**, 1 (1987).