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Observable Macroscopic Eigenstates

A droplet bouncing on a fluid interface can form a wave-particle association, when it becomes self-propelled by coupling to the wave it has generated. For this reason the resulting entity is best described as a “self-surfer”. This object has non-trivial characteristics because the wave-field contains a tunable memory of the droplet past trajectory. This specificity was already shown to generate some quantum-like behaviours in the high memory limit (1).

Here we will report on the motion of a self-surfer when it is submitted to a central force and thus spatially confined in a 2D axisymmetric potential well. This situation is experimentally obtained by using droplets containing some ferrofluid and submitted to an axisymmetric magnetic field gradient. At low memory the “classical” trajectory is circular. At high memory the most general trajectory is highly complex because the droplet visits regions already disturbed by its own past motion. However, in potential wells of specific discrete widths, stable self-organized orbits of various shapes (circles, lemniscates, trefoils…) emerge spontaneously(2).

Each of these possible stable orbits has both a quantized spatial extension and a quantized angular momentum. It can thus be described by two numbers and thus forms an eigenstate of a kind. This quantization arises from the spatio-temporal non-locality due to the path-memory. During its motion the bouncing of the droplet excites Bessel eigenmodes of the circular region in which it is confined. In turn, these mean waves induce trajectories that correspond to well defined values of the droplet angular momentum. Each state can thus be dually characterized by a specific droplet trajectory and by the dominance of a few eigenmodes of the global wave-field.

As for the more general complex trajectories we will show that their chaos results from an intermittency by which the system switches between the neighbouring eigenstates. At any given time the system is in one of these eigenstates. The intermittency phenomenon determines the typical time during which the system remains in each state and thus its probability.

(1) Y. Couder, E. Fort, Probabilities and trajectories in a classical wave-particle duality, Journal of Physics 361, 012001, (2012)
(2) S. Perrard, M. Labousse, M. Miskin, E. Fort,, and Y. Couder, Memory driven self organization, preprint 2013

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