The electrodynamic origin of the wave-particle duality

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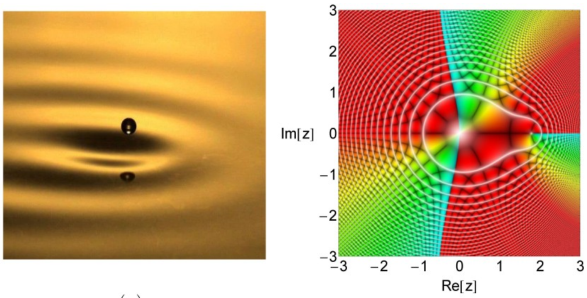
Abstract. We present a derivation of the wave-particle duality in terms of electrodynamic *self-interactions*. For this purpose, we abandon the current paradigm that describes electrodynamic bodies as point masses, and consider extended charged particles instead. We perform a stability analysis of the uniform motion of the particle, showing that very violent *nonlinear oscillations* are experienced when it is perturbed from such a state of motion. Finally, we compute the self-energy of the corpuscle and obtain a quantum potential, which produces a symmetry breaking of the Lorentz group, bridging classical electromagnetism and quantum mechanics.

Introduction

Hydrodynamical experimental models that serve as analogies to quantum mechanical systems have been developed during the last two decades. This experimental contemporary models allow us to clearly visualize how the dynamics of a possible quantum particle might be (Fig. 1a), and they share many features with the mechanics of quantum particles [1]. Fortunately, they are based on firmly established and understandable principles of nonlinear dynamical oscillatory systems and chaos theory. However, the existence of a *pilot wave* has not been proven yet in terms of physical fields concerning fundamental particles. In the present work we accomplish this task for a simple model of an electron.



(a) (b)

Fig. 1: (a) A bouncing silicon droplet on a vibrating bath, showing how De Broglie's pilot-wave dynamics arises in classical hydrodynamics (Image courtesy of Dan Harris and John Bush, MIT). (b) A domain color representation of the characteristic polynomial derived from the equation of motion to study the stability of the uniform motion of an electrodynamic body. An eigenvalue with real part greater than zero is present, destabilizing uniform motion and unleashing a *limit cycle* oscillation.

Results and Discussion

Using the retarded Liénard-Wiechert potentials, and assuming an electromagnetic origin of inertia [2,3], we have derived the equation of motion of a nonlinear oscillator for a charged extended electrodynamic body. The stability analysis of this *time-delayed* differential equation (Fig. 1b) reveals that the uniform motion of the body is destabilized through a Hopf bifurcation, producing a *self-oscillation* [4] with a frequency value that is closely related to the *zitterbewegung* appearing in the Dirac equation [2]. The mechanism triggering the oscillation relies on a feedback interaction between Coulombian and radiative fields among different charged parts of the particle, wich produces an electromagnetic pilot-wave. To conclude, we have computed the self-energy of the particle, deriving Einstein's mass-energy relation from Maxwell's electrodynamics, and also obtaining a new contribution that shares fundamental constants with Bohm's *quantum potential* [5]. Consequently, we propose that Newton's second law of motion emerges from classical electrodynamics [3] and that equations in which the concept of mass appears as an elementary parameter (as it occurs with the Schödinger or the Dirac equations), should not be considered as fundamental in physics [2].

References

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