Description of an elastic scattering process in the pilot-wave formulation

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Synopsis We apply De Broglie - Bohm theory to study the elastic collision of a particle by a force center in a stationary formulation. This approach allows us to clarify certain characteristics of the collision process, such as the occurrence of quantum vortices. It also provides an adequate framework for analyzing contextuality effects produced by the degree of coherence of the projectile's beam.

In 1926 Max Born [1] attempted to perform a quantum description of an atomic collision; not in terms of Schrödinger's or Heisenberg's formalisms but of De Broglie's pilot–wave formulation, arguing that it could provide a more satisfactory framework for that study. But this research program did not come to fruition until recently, when it was revalued as an advantageous option for the numerical calculation of various collision processes [2]. It is in this context that we developed a general stationary formulation of the scattering process in terms of De Broglie - Bohm formalism [3]. We evaluate the quantum trajectories for wave packets that are scattered by a dispersion center. In contrast to a previous analysis [4], we do not restrict our study to head-on collisions, but consider that the wave packets might have different impact parameters b uniformly distributed along a collimation region. This realistic description of the scattering process allows us to overcome the inconsistencies of a standard approach, where the incoming projectiles are described by plane-waves [5]; and by doing so it becomes particularly adequate for analyzing the effects produced by the characteristics of the projectile's beam.

In figure 1 we show the quantum trajectories for the dispersion of an off-centre non-spreading Gaussian wave packet with a well-defined forward impulse p by a model potential corresponding to an isotropic differential cross section. For the sake of simplicity we assume a two-dimensional system, being the generalization to the 3D case straightforward. Let us note that, since quantum trajectories cannot cross each other, only those in the outermost sides of the incoming flux can be scattered. The appearance of quantum vortices is evident in the figure. It can be demonstrated that, instead of being an exception, they represent a necessary ingredient of any scattering process. Finally, the cross section can be obtained by integrating the outgoing flux on the impact parameter b. The standard result is recovered for an infinite collimation region.

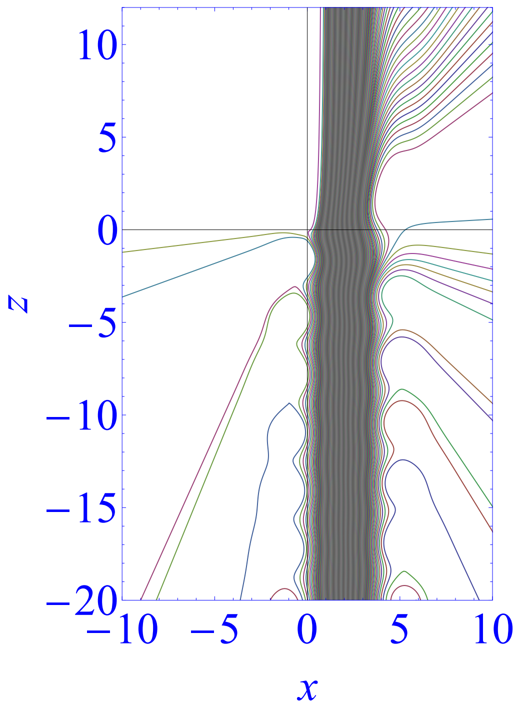

Figure 1. Quantum trajectories for the dispersion of a wave packet of width $\sigma = 1$, impulse $p = 1$ and impact parameter $b = 2$ a.u. by a force center at $(x, z) = (0, 0)$.

References

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