Quantum nonlocality revisited from the point of view of a local stochastic theory

Luis de la Peña, Ana María Cetto, and Andrea Valdés-Hernández

Instituto de Física, UNAM, Apartado postal 20-364, Ciudad Universitaria, 01000 Mexico, DF, Mexico

Nonlocality continues to pose some of the major conceptual difficulties for quantum mechanics. In the present work, we revisit quantum nonlocality by studying the problem of an otherwise classical particle immersed in a stochastic radiation field that includes the zero-point contribution. The corresponding stochastic Liouville equation in the phase space of the complete (particle+field) system is first reduced to a Fokker-Planck-type equation for the particle phase-space density $Q(x, p, t)$. In the transition to configuration space, which implies a partial averaging, an infinite hierarchy of equations is obtained for the particle; the first is the continuity equation for $\rho(x, t) = \int Q(x, p, t)dp$ and the second one is the equation for the transfer of momentum $\langle p\rangle(x)$, which contains in addition the higher-order moments $\langle p^n\rangle(x)$, coupling it to the rest of the hierarchy.

At this stage, the system is assumed to have reached a situation of detailed balance between the power lost by the particle through radiation reaction and the power gained by it from the zero-point field. The background field has played by then its most important role by leading the system to this situation, and one can therefore neglect the terms that represent mere radiative corrections to a first approximation. This leads to a decoupling of the first two equations from the rest of the hierarchy. The statistical information of the mechanical system is thus completely contained in the continuity equation plus an equation for the particle flux, which has an entirely classical shape except for an extra nonlocal term due to the fluctuations of the momentum (induced by the zero-point field). This nonlocal contribution is shown to be fully equivalent to the so-called quantum potential.

The couple of equations derived is recast, through simple mathematical transformations, into Schrödinger's equation and its complex conjugate, except for the value of Planck's constant which is determined in a separate paper [1]. The nonlocal information characteristic of the solutions of the Schrödinger equation is thus traced to the dynamics of the particle in momentum space, resulting from the fluctuations of the zero-point field. Nonlocality and quantum fluctuations emerge therefore as distinctive features of the quantum description, rather than being inherent properties of the system. Further, the theory is shown to allow, in principle, for a natural extension of the quantum description in phase space that is fully Kolmogorovian.

[1] A. M. Cetto and L. de la Pena, abstract submitted to this conference.