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Continuous measurement of position and momentum of a particle

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We define a model of time-continuous measurement of position and momentum of a quantum particle. We assume that meters are arranged in a regular grid in phase space. Each of these detectors is characterized by a coherent state centered around a phase space location (x_i, p_j) which defines a possible outcome of measurement. The post-measurement state is this coherent state. This way the measurement is associated with a random and sudden change, a "jump", of the particle wavefunction to one of the meter states. The probability of such a jump is proportional to the overlap of the particle's wavefunction with the detector state [1].
We use an open system formalism and treat detectors as the external reservoir. However, instead of directly solving the Gorini-Kossakowski-Sudarshan-Lindblad equation for the density operator, we use the Wavefunction Quantum Monte-Carlo formalism and generate single histories of the particle's wavefunction. We observe Zeno-like dynamics for sparse grids of detectors –the frequently monitored particle jumps back to the initial state due to observation which results in a kind of delayed motion. For a dense grid of detectors we show (in a few simple cases) that the average observed quantum trajectory follows a classical path. Obviously individual trajectories, because of the backaction of the meters, deviate from this mean. The studied examples indicate that the entire motion generated by the Wavefunction Quantum Monte Carlo method is equivalent (up to the two lowest moments of position and momentum distribution) to dynamics generated by Newton equations with stochastic white noise. The noise correlation function is uniquely determined by the detectors' parameters and their phase-space distribution [2].

[1] F. Gampel, M. Gajda, Phys. Rev. A 107, 012420 (2023).
[2] F. Gampel, M. Gajda, Acta Phys. Pol. 143, S131 (2023).

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