Mass-independent test of quantumness of a massive object

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A cutting-edge research enterprise in contemporary physics is to explore realizable schemes towards empirically checking the validity of the quantum mechanical principle of superposition of states in the macroscopic regime, together with demonstrating its incompatibility with the world view based on the pivotal classical notion of macrorealism (MR). The goal is to expand as much possible the macroscopic domain of evidencing nonclassicality. This has also potentiality in providing useful empirical constraints on suggested modifications of quantum dynamical evolution in the macroscopic limit (such as the models of spontaneous wave function collapse), which suppress superposition of states at the macrolevel. Nonclassical massive matter states are also a resource for witnessing nonclassical gravity. Though a variety of "macroscopicity" measures have been invoked for testing MR in different contexts, there is not yet any practical scheme which can evidence the irreducible quantumness of an arbitrarily large mass. Motivated by this, we investigate the quantum violation of MR for arbitrary masses in a harmonic potential.

While testing MR, and through it nonclassicality, can be, in principle, much easier than creating highly nonclassical states, in practice it imposes very high demands on the initial control of parameters, as well as extremely precise measurements. To this end, we use standard tools for probing quantum violation of MR, but incorporate crucial modifications: while usual tests use the same measurement arrangement at successive times, here we use two different measurement arrangements. This yields a striking result: a *mass-independent* violation of MR is possible. In fact, our adaptation enables probing quantum violations for literally any mass, momentum, and frequency. Moreover, our proposal only requires measurements on macroscopic oscillators to the accuracy of the standard quantum limit, as well as only knowing parameters to this precision without requiring them to be tuned. These should drastically reduce the experimental effort in testing the nonclassicality of massive objects ranging from atomic ions to mirrors in LIGO.

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