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Collapse models, the quantum-classical transition, and experimental searches

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Physics at the quantum-classical border is one of the crucial fields of today's research, both theoretical and experimental. One of the challenging questions is to understand if, and under which conditions, quantum linearity fails when the size and complexity of the system increases [1,2]. The exploration of this question has substantial consequences because if the quantum superposition principle fails beyond a certain scale (e.g., a mass scale), then it necessitates the modification of quantum theory (which may even result in a better scenario for unifying quantum theory with gravity [3]). Collapse models are one possible way among many, to modify the standard quantum theory in a fully-consistent way [1]. Collapse model assumes a universal noise field that, when acting on matter, introduces non-linear effects on the dynamics, which explains the collapse of the wave function. In other words, one can derive the random localization of the wave function at the end of a measurement, of course with the correct quantum probabilities. The strength of the collapse process scales with the size of the system, thus the wave function of microscopic systems can be superimposed, while macroscopic objects are always well-localized [1]. Recently, there has been rapid experimental progress in revealing quantum features such as particle-wave duality for large objects with tiny de Broglie wavelength of only a few hundred femtometer [4]. This progress provides the possibility to search for tests of collapse models. In this regard, quite a few new experimental schemes have been proposed. Most proposals are based on the natural idea of creating a macroscopic quantum superposition in space, in order to test the superposition principle. Creating macroscopic superpositions is very difficult, source of formidable technological challenges. We propose an alternative approach by measuring the fluctuating properties of light interacting with a system (e.g., a molecule or an optomechanical oscillator) [5]. Here, the collapse manifests as an extra broadening and shift in the spectral density. The most important advantageous of this new approach is that here there is no need for the preparation of a quantum superposed state. We speculated that the corresponding experimental realization is well within reach.

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