Macroscopic Quantum Tunneling in Bose-Einstein Condensates

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Abstract:

I present three studies on macroscopic quantum tunneling of Bose-Einstein condensates. First, I show how even at the simplest mean field level already the problem of escape through a barrier has new features compared to single particle physics: the tunneling time is not the inverse of the rate and interactions allow one to tune from bound to quasi-bound to unbound states freely [1]. Second, I show how tunneling in a double-well system leads to Josephson junction and Schrodinger cat (NOON state) physics. I demonstrate that although a very small bias or tilt in the potential can destroy Cat-like states, by intentional use of bias the many body wavefunction can be used to protect such states from destruction (or internal decoherence) [2]. Third, I present a full many-body calculation of entangled quantum dynamics of the escape problem [3], exploring entanglement, number correlations, and other features not accessible by instanton or other methods. I show that the tunneling process is non-smooth, and actually occurs in bursts. When approximately half the particles have tunneled out of the well, the particles remaining are maximally entangled with the escaped portion. Number fluctuations greatly modify the escape time beyond mean field predictions. Preliminary indications are that the time derivative of number fluctuations serves as a witness to the spatial entropy of entanglement. In summary, these three views on macroscopic quantum tunneling show that even a weakly interacting many body system already has significantly different features on all levels as compared to the single particle problem.

References:

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