Time scales at quantum phase transitions

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The time evolution of quantum wave packets may lead to interesting collapse and revival phenomena. Propagating wave packets initially evolve quasiclassically and oscillate with a classical period but eventually spread and collapse. At later times, multiples of a revival time Tr, wave packets regain their initial wave form and behave quasiclassically again. Additionally, at times that are rational fractions of Tr, the wave packet temporarily splits into a number of scaled copies called fractional revivals. Revivals and fractional revivals have attracted a great interest during the past decades. They have been investigated theoretically in nonlinear quantum systems, atoms and molecules (including Graphene), and observed experimentally in, among others, Rydberg atoms, molecular vibrational states or Bose-Einstein condensates. Recently, methods for isotope separation, number factorization as well as for wave packet control have been put forward that are based on revival phenomena.

Here, the concept of quantum revivals is extended to many-body systems and the implications of traversing a quantum phase transition are explored. By analyzing three different models, the vibron model for the bending of polyatomic molecules, the Dicke model for a quantum radiation field interacting with a system of two-level atoms, and Lipkin-Meshkov-Glick model, we show evidence of revival behavior for wave packets centered around energy levels as low as the fundamental state. Away from criticality, revival times exhibit smooth, nonsingular behavior and are proportional o the system size. Upon approaching a quantum critical point, they diverge as power laws with associated critical exponents and scale with the system size, although the scaling is no longer linear.

Excited states quantum phase transitions also influence the revival behavior of wave packets, but in this case revival times appear to show softer singularities. In particular, for the vibron model the singularities are logarithmic in nature.

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