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Constant of motion identifying excited-state quantum phases and some applications to quantum optical models

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ESQPTs have an important drawback compared with quantum and thermal phase transitions: it is not easy to define two different phases, with different equilibrium properties, separated by the corresponding critical energy. In this talk, I will review our work [1], where we proposed a way to address this issue. We find an operator which is a constant of motion only in one of these two phases. This allows us to define two different phases at both sides of the ESQPT: one in which equilibrium thermodynamics depends on this new constant of motion, and another one in which this observable plays no relevant role. The main characteristic of this operator is that it acts like a discrete symmetry in the first of these phases, with just two possible eigenvalues. Hence, we propose that the trademark of this phase in many systems displaying ESQPTs, like the Dicke and Rabi models, is having two different discrete symmetries: parity and this new constant of motion. We show analytically that these two operators are noncommuting. This explains one of the typical features of this kind of ESQPTs: the transition from degenerate doublets to non-degenerate energy levels. Numerical results in the Rabi and Dicke models show that the expectation values of observables in equilibrium crucially depend on this new constant of motion in the corresponding phase. Furthermore, its mere existence implies a number of relevant consequences for example linked to chaos [2], and allowing for the generation of certain cat states [3].

References:

[1] A. L. Corps and A. Relaño, \textit{Constant of Motion Identifying Excited-State Quantum Phases}, Phys. Rev. Lett. \textbf{127}, 130602 (2021).
[2] A. L. Corps, R. A. Molina and A. Relaño, \textit{Chaos in a deformed Dicke model}, J. Phys. A: Math. Theor. \textbf{55}, 084001 (2022).
[3] A. L. Corps and A. Relaño, \textit{Energy cat states induced by a parity-breaking excited-state quantum phase transition}, Phys. Rev. A \textbf{105}, 052204 (2022).

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