Invitation

Photon-blockade breakthrough as a first-order dissipative quantum phase transition – theory & experimental realization

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Nonequilibrium phase transitions exist in damped-driven open quantum systems when the continuous tuning of an external parameter leads to a transition between two robust steady states. In second-order transitions this change is abrupt at a critical point, whereas in first-order transitions the two phases can coexist in a critical hysteresis domain.

Here, I present a first-order dissipative quantum phase transition, together with its observation in a typical driven circuit quantum electrodynamics setting [1]. The microscopic basis of the transition is that the photon blockade of the driven cavity-atom system is broken when increasing the drive power [2, 3]. The observed experimental signature is a bimodal phase space distribution with varying weights controlled by the drive strength. The measurements show an improved stabilization of the classical attractors up to the millisecond range when the size of the quantum system is increased from one to three artificial atoms.

In the second half of the talk I investigate the question of how a phase transition can occur in such a small quantum system. By unraveling the stationary solution into quantum trajectories, I describe the nature of the coexistence of phases. There exists a well-defined thermodynamic limit, where the bistability solution develops into the first-order phase transition. I present the numerical calculation of the finite-size scaling exponent [4]. Importantly, even in this thermodynamic limit, the stability of phases originates from the discrete spectrum of the small quantum system. The switching behavior is induced by the continuous quantum measurement of the system through the environment, based on the fact that the dim phase remains in a strongly nonclassical state even in the thermodynamic limit.

References

[1] J. M. Fink, A. Dombi, A. Vukics, A. Wallraff, and P. Domokos, *Observation of the Photon-Blockade Breakdown Phase Transition*, Phys. Rev. X 7, 011012 (2017).

[2] A. Dombi, A. Vukics, and P. Domokos, *Bistability Effect in the Extreme Strong Coupling Regime of the Jaynes-Cummings Model*, Eur. Phys. J. D 69, 60 (2015).

[3] H. J. Carmichael, Breakdown of Photon Blockade: *A Dissipative Quantum Phase Transition in Zero Dimensions*, Phys. Rev. X 5, 031028 (2015).

[4] A. Vukics, A. Dombi, J. M. Fink, P. Domokos, *Finite-size scaling of the photon-blockade breakdown dissipative quantum phase transition,* arXiv:1809.09737 (2018).

Friday, Januar 11th 2019
15:30 pm
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