Quantum Jumps in Amplitude Bistability: Tracking a Coherent and Invertible State Localization

Themistoklis Mavrogordatos

Stockholm University, Department of Physics, Fysikum, AlbaNova University Center, SE-10691, Stockholm, Sweden

We investigate the nature of quantum jumps occurring between macroscopic metastable states of light in the open driven Jaynes-Cummings (JC) model [1]. We find that, in the limit of zero spontaneous emission considered in [2], the jumps from a high-photon state to the vacuum state entail two stages. The first part is coherent and modelled by the localization of a state superposition, in the example of a null-measurement record predicted by quantum trajectory theory. The underlying evolution is mediated by an unstable state, which often splits to a complex of states, identified by the conditioned density matrix and the corresponding *quasi*probability distribution of the cavity field. The unstable state subsequently decays to the vacuum to complete the jump.

Coherence in the localization allows for inverting the null-measurement photon average about its initial value, to account for the full switch which typically lasts a small fraction of the average cavity lifetime; an asymptotic law for the jump time is established in high-amplitude bistability. We find that the JC interaction is particular in stabilizing the attractors associated with amplitude bistability, as opposed to the 'weak-coupling limit' of the Kerr nonlinearity. Further, spontaneous emission degrades coherence in the localization, and prolongs the jumps.

The observed signatures of coherence can be employed to explore the absence of detailed balance in quantum amplitude bistability, already deduced at the level of stochastic Maxwell-Bloch equations [3]. At the quantum level, there is no coherent localization in upward jumps; photon emissions condition single-state cavity fields. Operationally, we find that while the path taken to attain a bright state can be tracked in detail by heterodyne current records produced by the free decay of the cavity mode initialized in a conditioned state of JC bistability. On the other hand, no interference fringes are expected to be seen in the homodyne current histograms, as is the case for the downwards jumps.

[1] Th. K. Mavrogordatos, Annalen der Physik 538, e00388 (2026).

[2] H. J. Carmichael, Phys. Rev. X 5, 031028 (2015).

[3] A. Denisov, H. M. Castro-Beltran, and H. J. Carmichael, Phys. Rev. Lett. 88, 243601 (2002).