

Geometry and restoration of the quantum Mpemba effect beyond weak-coupling regime in the spin–boson model

Paolo Chirico¹, Grazia Di Bello^{2,3}, Carmine Antonio Perroni^{3,4}, Giulio De Filippis^{3,4}

1. Scuola Superiore Meridionale, Largo San Macellino 10, I-80138 Napoli, Italy

2. Dip. Di Fisica E. Pancini - Università di Napoli Federico II - I-80126 Napoli, Italy

3. INFN, Sezione di Napoli - Complesso Universitario Monte S. Angelo - I-80126 Napoli, Italy

4. SPIN-CNR and Dip. di Fisica E. Pancini - Università di Napoli Federico II - I-80126 Napoli, Italy

Abstract: We investigate the quantum Mpemba effect in dissipative two-level systems coupled to a bosonic environment. We identify regimes where states initially farther from equilibrium relax faster than states closer to it.

The Mpemba effect refers to the counterintuitive phenomenon where a system initially farther from equilibrium may relax faster than one that is initially closer. Its extension to the quantum regime has recently attracted significant interest, particularly in open quantum systems [1]. Here, we analyze the emergence of the **quantum Mpemba effect** in a dissipative two-level system coupled to a continuum of bosonic modes [2]. The exact system dynamics was numerically computed using tensor networks techniques [3]. It has been shown that the relaxation process can be interpreted as the combination of two decaying modes: a fast decay due to the populations and a slower one due to coherences [1]. The interplay between these modes plays a crucial role in the relaxation speed. We focus on the dependence of the relaxation dynamics on a control parameter α , which modulates the system-bath interaction [2]. Numerical simulations show that the excited state corresponds to the fastest decaying mode, and so the more the population is the faster will be the relaxation. Furthermore, we show that increasing α leads to an almost instantaneous relaxation regime, highlighting a strong enhancement of dissipative processes. The occurrence of the effect is clearly visible in the evolution of the trace distance Fig.1a. We find an explanation for such an effect is that in excited state hemisphere (Fig.1b) further states have more populations, and so the fast mode weights more in the relaxation process.

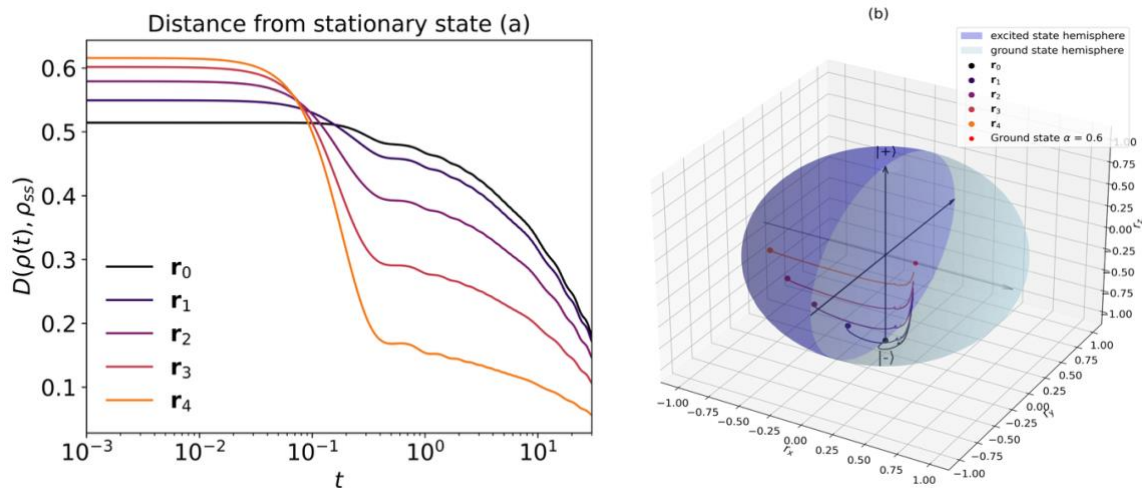


Fig. 1 (a) shows the distance from the stationary state. The crossing of the curves signals the occurrence of the effect. (b) shows the dynamics on the Bloch sphere, giving a graphical representation of the dynamics. Here $\alpha = 0.6$ and $r_i = (-\cos(\phi_i), 0, \sin(\phi_i))$, with $\phi_i \in \{0, 0.1, 0.2, 0.3, 0.4\}$.

References

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