Objectivity in non-Markovian spin-boson model

Aniello Lampo[1], Jan Tuziemski[2], Jarosław Korbicz[2] and Maciej Lewenstein[1,3]

[1]ICFO - Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain.
[2]Faculty of Applied Physics and Mathematics, Technical University of Gdańsk, 80-233 Gdańsk, Poland.
[3]ICREA, Psg. Lluis Companys 23, E-08010 Barcelona, Spain.

Quantum mechanics is one of the most successful theories, correctly predicting a huge class of physical phenomena. Its validity remains confined to the microscopic regime, where such a theory provides a good explanation of the behavior of the constituents of matter. Contrariwise, there is no trace of quantum effects on macroscopic scales, fully ruled by classical physics. Accordingly, one natural question arises: how the classical features of the macroscopic world emerge from the underlying quantum domain?

In particular, from the everyday experience we are accustomed to perceive nature as *objective*: if two different observers measure the same quantity in two identical systems prepared in the same state, they surely obtain the same outcome. This point of view has been fundamentally challenged by quantum mechanics, since an act of observation generally modifies the state of a system. So it is natural to wonder how the objectivity of the classical theory emerges from not objective quantum one.

An important contribution to such a problem has been given by *quantum darwinism* attributing objectification of a quantum system to its unavoidable interaction with the environment [1]. Precisely, the environment is considered divided in several different portions, storing the same information about the central system, which can be extracted by observers.

Another important step beyond has been accomplished in [2] where the authors focused on the analysis of objectivity in terms of states: we have objectivity if and only if the post-interaction state of the central system plus the observed portion E posses the so-called *spectrum broadcast structure* (SBS):

$$\rho_{S,fE} = \sum_i p_i |x_i\rangle\langle x_i| \otimes \rho_i^{E_i} ... \otimes \rho_i^{E_{fN}} \tag{1}$$

with $\{|x_i\rangle\}$ a pointer basis of the central system, p_i initial pointer probabilities, and some states of the observed parts of the environment $\{E_1, ..., E_{fN}\}$ with mutually orthogonal supports.

The main purpose of our (unpublished) paper is to detect SBS for the spin-boson model, which consists of a two-level system interacting with a large reservoir of bosonic modes [3]. This model plays an important role in quantum computing, as well as in experiments on macroscopic quantum coherence, for instance in those aimed to analyse the role of quantum coherence in biological systems.

An important part of the work is devoted to explore the behavior of the model in the non-Markovian regime. By non-Markovianity we mean the presence of memory effects making the evolution of the central system strongly dependent by its past history. This situation constitutes the rule rather than the exception, especially in the low-temperature regime, or when the interaction between the central system and the surrounding degrees of freedom gets sufficiently strong. **We propose thus to study how non-Markovianity affects (or not) objectification processes**.

[1] W.H. Zurek, *Quantum Darwinism*, Nat. Phys. **12**, 181 (2009).

[2] J.K. Korbicz, P. Horodecki, and R. Horodecki, *Quantum-correlation breaking channels, broadcasting scenarios, and finite Markov chains*, Phys. Rev. A **4**, 042319 (2012).

[3] A.J. Leggett, S. Chakravarty, A.T. Dorsey, M.P.A. Fisher, A. Garg, and W. Zwerger, *Dynamics of the dissipative two-state system*, Rev. Mod. Phys. **59**, 1 (1987).