Quantum Sensing by Stochastic Quantum Zeno

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A system under constant observation is practically freezed to the measurement subspace. If the system driving is a random classical field, the survival probability of the system in the subspace becomes a random variable described by the Stochastic Quantum Zeno Dynamics (SQZD) formalism. Here, we study the time and ensemble average of this random survival probability, and demonstrate how time correlations in the noisy environment determine whether the two averages do coincide or not. These environment time correlations can potentially generate non-Markovian dynamics of the quantum system depending on the structure and energy scale of the system Hamiltonian. We thus propose a way to detect time correlations of the environment by coupling a quantum probe system to it and observing the survival probability of the quantum probe in a measurement subspace [1].
Recently, an ergodicity breaking effect in SQZD has been experimentally observed by atom-chips [2]. More specifically, we have shown how the ergodicity property is present when an open quantum system is continuously perturbed by an external environment effectively observing the system at random times while the system dynamics approaches the quantum Zeno regime. In this context, by large deviation theory we analytically show how the most probable value of the probability for the system to be in a given state eventually deviates from the non-stochastic case when the Zeno condition is not satisfied. These results were then tested by ultra-cold Rubidium atoms prepared on an atom-chip platform.
Finally, we demonstrate how the sensitivity of the measurement is described by a functional version of the Fisher information [3,4], as well as sensing protocols based on Optimal Control. In particular, we analytically study the distinguishability of two different stochastic measurement sequences in terms of a Fisher information measure depending on the variation of a function, instead of a finite set of parameters. Therefore, we expect that these results will further contribute to the development of new schemes for quantum sensing technologies, where nanodevices may be exploited to image external structures or biological molecules via the surface field they generate.

[l] M.M. Müller et al., Sci. Rep. **6**, 38650 (2016).
[2] S. Gherardini et al., Quantum Sci. Technol **2**, 015007 (2017).
[3] M.M. Müller et al., Phys. Rev. A **94**, 042322 (2016).
[4] M.M. Müller et al., paper in preparation (2017).