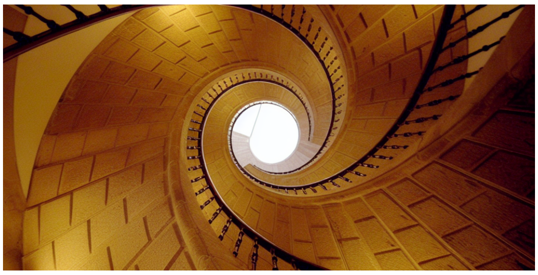

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Entanglement-assisted, noise-assisted, and monitoring-enhanced quantum bath tagging

The possibility of discriminating the statistics of a thermal bath using indirect measurements performed on quantum probes is presented. The scheme relies on the fact that, when weakly coupled with the environment of interest, the transient evolution of the probe toward its final thermal configuration is strongly affected by the fermionic or bosonic nature of the bath excitations. Using figures of merit taken from quantum metrology such as the Holevo-Helstrom probability of error and the quantum Chernoff bound, we discuss how to achieve the greatest precision in this statistics tagging procedure, analysing different models of probes and different initial preparations and by optimizing over the time of exposure of the probe. [1]
We then extend these studies to a more generic problem that consists in discriminating between two baths with disparate constituents at unequal temperatures. Notably there exist temperature regimes in which the presence of coherence in the initial state preparation is beneficial for the discrimination capability. We also find that nonequilibrium states are not universally optimal and detail the conditions in which it becomes advantageous to wait for complete thermalization of the probe. These concepts are illustrated in a linear-optical simulation. [2]
We finally analyse the capability of discriminating the statistical nature of a thermal bath in the presence of three different types of side resources: prior entanglement between the probing system and an external (dynamically neutral) memory element, the interaction between the probe and an auxiliary bath, and the continuous monitoring of the system mediated by real-time measurements of the auxiliary bath. We discuss in detail how to obtain improved performances in the discrimination by considering different kinds of interactions, i.e., different jump operators, and different monitoring strategies corresponding to continuous homodyne detection and photodetection. We find that the presence of the auxiliary environment can be beneficial, allowing bath discrimination in regimes where in the standard scenario discrimination is not possible. We then show how additionally monitoring this environment, via either continuous homodyne detection or photodetection, is naturally advantageous for quantum bath tagging, in particular in the long-time limit where a large improvement in the discrimination performance is indeed observed. [3]

References:
[1] D. Farina, V. Cavina, V. Giovannetti, Phys. Rev. A 100 (4), 042327 (2019).
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[3] D. Farina, V. Cavina, M. G. Genoni, and V. Giovannetti, Phys. Rev. A 106, 042609 (2022).

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