1.3.30 Quantum Metrology

By making use of quantum-mechanical features, such as quantum superposition, entanglement, or squeezing, we are able to go beyond classical technologies. One of such promising ideas is "quantum metrology" because of its possible applications. When one wishes to estimate some quantity or parameter of a physical system, one typically tries to do it by analyzing data collected by performing a number of independent and identical experiments, or by sending a number of independent probes to the target.

In Ref. [1,8] we identified the optimal quantum pure states of identical bosonic particles for applications in quantum metrology, in particular in the estimation of a single parameter for the generic two-mode interferometric setup.

In Ref. [2,6] we introduced, a quantifier for the best achievable accuracy for temperature estimation via local measurements. In Ref. [10] a scheme for improving the sensitivity of quantum thermometry was proposed where the sensing quantum system used to recover the temperature of an external bath is dynamically coupled with an external ancilla (a meter) via an Hamiltonian coupling – see Fig. 1.

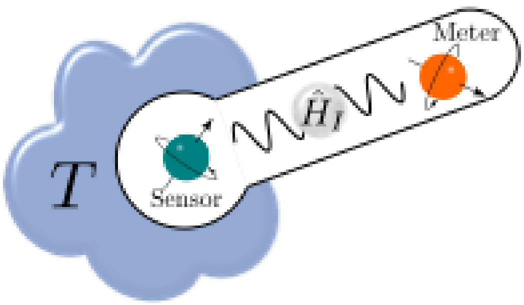

Figure 1. Schematic representation of the model discussed in Ref. [10] – figure taken from the paper. Here the temperature T is recovered by studying the effect it induces on the meter system that is coupled with a sensor that is in constant contact with the bath.

In Ref. [7,9] we studied the efficiency of estimation procedures where the temperature of an external bath is indirectly recovered by monitoring the transformations induced on a probing system that is put in thermal contact with the bath. In particular we compare the performances of sequential measurement schemes where the probe is initialized only once and measured repeatedly during its interaction with the bath, with those of measure and re-prepare approaches where instead, after each interaction-and-measurement stage, the probe is reinitialized into the same fiduciary state. From our analysis it is revealed that the sequential approach, while being in general not capable of providing the best accuracy achievable, is nonetheless more versatile with respect to the choice of the initial state of the probe, yielding on average smaller indetermination levels. In Ref. [4] the problem of estimating a parameter of a quantum system through a series of measurements performed sequentially on a quantum probe is analyzed in the general setting where the underlying statistics is explicitly non-i.i.d. In this setting we gave a generalization of the central limit theorem in the present context, which under fairly general assumptions shows that as the number N of measurement data increases the probability distribution of functionals of the data (e.g., the average of the data) through which the target parameter is estimated becomes asymptotically normal and independent of the initial state of the probe.

In Ref. [11] the possibility of discriminating the statistics of a thermal bath using indirect measurements performed on quantum probes was 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.

In Ref. [3] we presented a quantifier of non-classical correlations for bipartite, multi-mode Gaussian states. In Ref. [5] we considered bipartite systems as versatile probes for the estimation of transformations acting locally on one of the subsystems. We investigate what resources are required for the probes to offer a guaranteed level of metrological performance, when the latter is averaged over specific sets of local transformations. Our analysis contrasts and complements the recent series of studies focused on the minimum, rather than the average, performance of bipartite probes in local estimation tasks, which was instead determined by quantum correlations other than entanglement. We provide explicit prescriptions to characterize the most reliable states maximizing the average skew information, and elucidate the role of state purity, separability and correlations in the classification of optimal probes.

References

[1] A. De Pasquale, P. Facchi, G. Florio, V. Giovannetti, K. Matsuoka, K. Yuasa, *Two-Mode Bosonic Quantum Metrology with Number Fluctuations*, Physical Review A **92**, 042115 (2015).

[2] A. De Pasquale, D. Rossini, R. Fazio, V. Giovannetti, *Local quantum thermal susceptibility*, Nature Communications **7**, 12782 (2016).

[3] L. Rigovacca, A. Farace, A. De Pasquale, V. Giovannetti, *Gaussian discriminating strength*, Phys. Rev. A **92**, 042331 (2015).

[4] D. Burgarth, V. Giovannetti, A.N. Kato, K. Yuasa, *Quantum estimation via sequential measurements*, New J. Phys. **17**, 113055 (2015).

[5] A. Farace, A. De Pasquale, G. Adesso, V. Giovannetti, *Building versatile bipartite probes for quantummetrology*, New J. Phys. **18**, 013049 (2016).

[6] G. De Palma, A. De Pasquale, V. Giovannetti, *Universal locality of quantum thermal susceptibility*, Phys. Rev. A **95**, 052115 (2017).

[7] A. De Pasquale, K. Yuasa, V. Giovannetti, *Estimating temperature via sequential measurements*, Phys. Rev. A **96**, 012316 (2017).

[8] T. Matsubara, P. Facchi, V. Giovannetti, K. Yuasa, *Optimal Gaussian metrology for generic multimodeinterferometric circuit*, New J. Phys. **21**, 033014 (2019).

[9] V. Cavina, L. Mancino, A. De Pasquale, I. Gianani, M. Sbroscia, R.I. Booth, E. Roccia, R. Raimondi, V. Giovannetti, M. Barbieri, *Bridging thermodynamics and metrology in nonequilibrium quantum thermometry*, Phys. Rev. A **98**, 050101 (2018).

[10] A.H. Kiilerich, A. De Pasquale, V. Giovannetti, *Dynamical approach to ancilla-assisted quantum thermometry*, Phys. Rev. A **98**, 042124 (2018).

[11] D. Farina, V. Cavina, V. Giovannetti, *Quantum bath statistics tagging*, Phys. Rev. A **100**, 042327 (2019).