Quantum thermodynamic derivation of the energy resolution limit in magnetometry

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It was recently demonstrated that a large number of magnetic sensing technologies satisfy the energy resolution limit, which connects a quantity composed by the variance of the magnetic field estimate, the sensor volume and the measurement time, and having units of action, with $\hbar$. A first-principles derivation of the energy resolution limit is still elusive. We here present such a derivation based on quantum thermodynamic arguments. We show that the energy resolution limit is a result of quantum thermodynamic work associated with quantum measurement and Landauer erasure, the work being exchanged with the magnetic field. We apply these considerations to atomic magnetometers and SQUIDS. Regarding the former, we unravel a new spin correlation effect relevant to the magnetic noise produced by atomic vapors.

[1] I. Kominis, arXiv:2405.14687v2