Quantum sensing enhancement in monitored dissipative time crystals

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We investigate quantum-enhanced parameter estimation through continuous monitoring in open quantum systems that exhibit a dissipative time crystal phase. We first analytically derive the global quantum Fisher information (QFI) rate for boundary time crystals (BTCs), demonstrating that within the time-crystal phase, the ultimate precision exhibits a cubic scaling N^3 with the system size. We then generalize this finding to a broader class of dynamics, including the transverse collective dephasing (TCD) model, which achieves a time-crystal phase through a closing Liouvillian gap without requiring a dissipative phase transition. We proceed to numerically demonstrate that this maximal global QFI rate is experimentally attainable for both the BTC and TCD models, even at finite system sizes, via continuous homodyne and photodetection. Moving towards practical implementations, we analyze the precision limits under inefficient detection, revealing a critical difference: for BTC dynamics, inefficiencies asymptotically restore a classical scaling, and only a constant-factor quantum advantage remains possible. In contrast, for TCD dynamics, a super-classical scaling is still in principle observable, and our numerical simulations confirm its presence, even under inefficient measurement conditions, establishing the TCD model as a highly robust platform for quantum metrology.

References

[1] E. O'Connor *et al.*, arXiv:2508.15448 (2025)