Quantum metrology with non-Gaussian spin states

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The well-known spin squeezing coefficient efficiently quantifies the sensitivity and entanglement of Gaussian states [1,2]. However, this coefficient is insufficient to characterize the much wider class of non-Gaussian quantum states that can generate even larger sensitivity gains.

In this talk, we present a non-Gaussian extension of spin squeezing based on reduced variances of nonlinear observables that can be optimized under relevant constraints [3]. We determine the scaling of the sensitivity enhancement that is made accessible from increasingly complex quantum states generated by one-axis-twisting in the presence of relevant noise processes [4,5].

We analytically determine the quantum gain offered by slightly over-squeezed non-Gaussian spin states, which are accessible in state-of-the-art experiments. Our results also produce optimal measurement observables that extract maximal information about the parameter of interest from these states. Using these techniques, quantum metrology measurements can significantly outperform current standard strategies based on Gaussian states (Fig. 1).

When considering the effect of different, experimentally relevant noise processes, we identify a discontinuous scaling law of the optimal sensitivity. Not unlike a phase transition, this transition becomes sharp only in the thermodynamic limit, whereas it is washed out by finite-size effects otherwise.

Our analytical results provide recipes for optimal quantum-enhanced metrology measurements in atomic systems with non-Gaussian spin states in realistic conditions.

References

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Figures

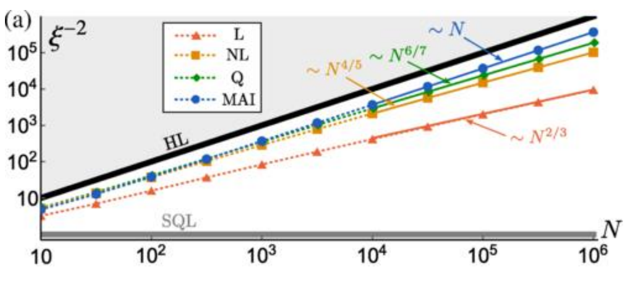

Figure 1: Comparison of the sensitivity scaling of different non-Gaussian metrology strategies (NL, Q, MAI) with that of the standard Gaussian method (L) and the Heisenberg limit (HL).