Quantum Kalman Filtering and the Heisenberg Limit in Atomic Magnetometry

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abstract The shotnoise detection limit in current high-precision magnetometry Romalis2003 is a manifestation of quantum fluctuations that scale as $1/\sqrt{N}$ in an ensemble of $N$ atoms. Here, we develop a procedure that combines continuous measurement and quantum Kalman filtering Belavkin1999 to surpass this conventional limit by exploiting conditional spin-squeezing to achieve $1/N$ field sensitivity. Our analysis demonstrates the importance of optimal estimation for high bandwidth precision magnetometry at the Heisenberg limit and also identifies an approximate estimator based on linear regression.