

# Quantum enhanced estimation of diffusion

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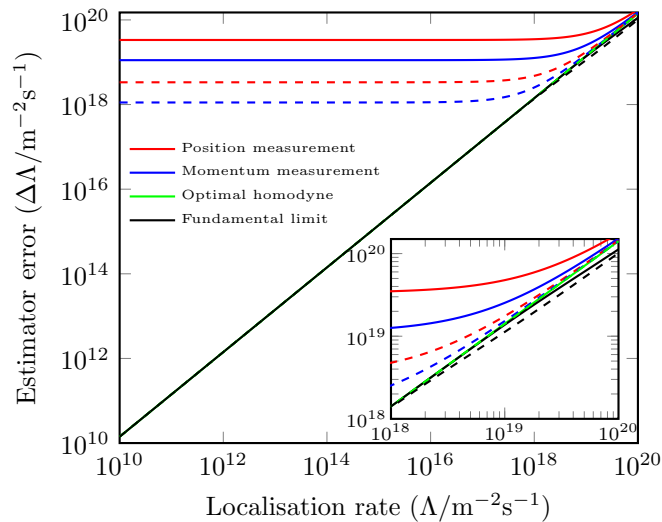
## Abstract

Collapse models propose a non-deterministic mechanism which suppress quantum effects in macroscopic objects while having negligible impact on microscopic systems. We explore the attainable precision for such localisation rates when a free particle is allowed to evolve, with particular focus around the parameters of the proposed MAQRO mission. This allows us to identify potential improvements from mechanical squeezing, 10 dB of which could compensate for an order of magnitude reduction in free-fall time.

Intrinsic decoherence effects have been predicted through collapse models which could explain the natural absence of quantum effects in macroscopic systems [1] and theories of quantum gravity [2]. Localisation of a test particle due to collapse models causes additional spreading of the particle's wavefunction. This effect appears as dephasing in the position basis—momentum diffusion—of a continuous variable quantum system. We evaluate the effectiveness of estimating such diffusion in quantum-mechanical systems with a free-particle Hamiltonian following an evolution

$$\frac{\partial \rho}{\partial t} = -\frac{i}{\hbar} \left[ \frac{\hat{p}^2}{2m}, \rho \right] - \Lambda [\hat{x}, [\hat{x}, \rho]]. \quad (1)$$

Our analytical results [3] can for example be applied to the proposed MAQRO mission [4] for which the precision is plotted in the figure below. In the context of the MAQRO mission we see the potential to improve by several orders of magnitude over measuring the particle's position. Squeezing can also reduce the required free-fall time, with 10 dB compensating for an order of magnitude reduction in free-fall time.



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- [4] R. Kaltenbaek et al., *Macroscopic Quantum Resonators (MAQRO): 2015 update*, EPJ Quantum Technology **3**, 5 (2016).