Stochastic Soliton Dynamics in Finite Temperature Quantum Gases

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Abstract:

A number of recent experiments with ultracold quantum gases has led to the observation and study of dark solitons. At low temperatures, solitons were observed to oscillate in the harmonic confining potential [1], while the presence of a thermal cloud has been predicted to lead to a gradual increase in the oscillation amplitude due to damping. Previous work has focused on the average behaviour of solitons in such systems, often leading to very accurate predictions [2]. However, an accurate modelling of the motion of such a macroscopic structure through a medium requires consideration of any residual fluctuations in the medium, an effect which is typically present in realistic experiments.

We present [3] an ab-initio discussion of soliton dynamics which takes account of the anticipated shot-to-shot variation in the soliton trajectories between different experimental realisations at all nonzero temperatures. We also undertake a statistical analysis of soliton trajectories, and identify an optimal regime for the experimental characterisation of this effect.

Our analysis is based on the Stochastic Gross-Pitaevskii equation [4] which accounts for shot-to-shot fluctuations in both the density and the phase of the underlying medium, the latter becoming increasingly important in highly-elongated geometries. This model not only provides an ab initio determination of the average dissipation experienced by the soliton, but most importantly it also describes time-dependent random stochastic kicks to the propagating soliton, thereby modelling the experimentally-relevant shot-to-shot variations.

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References:
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