Positive-P Simulations of Cooling Dynamics in a Trapped One-Dimensional Bose Gas

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Recent experiments have shown that statistical properties of ultracold gases, including atom-number fluctuations and correlation functions, can be measured directly and may depend strongly on the statistical ensemble [1]. This motivates theoretical models that describe not only average quantities after cooling, but also fluctuations and correlations in the final state.

We study cooling dynamics in a one-dimensional gas of weakly interacting bosons confined in a harmonic trap. Starting from a thermal state above the characteristic temperature, we model the gas as an open quantum many-body system governed by a master equation. Cooling is introduced through particle loss, including protocols where atoms are removed when they move far from the trap center or when they occupy high-energy states.

The continuous many-body problem is represented on a lattice using the Discrete Variable Representation and simulated with the Positive-P representation [2], which maps the master equation onto stochastic Itô equations. This allows us to sample the initial thermal state directly and follow the cooling dynamics through an ensemble of stochastic trajectories.

We analyze total atom-number fluctuations, first- and second-order correlations, the condensate fraction, and condensate-number fluctuations. These observables allow us to characterize how cooling shapes coherence, correlations, and fluctuations in the final gas, and may help interpret experimentally observed statistics of ultracold gases after cooling.

[1] M. B. Christensen *et al.*, *Phys. Rev. Lett.* **126**, 153601 (2021).
[2] P. Deuar *et al.*, *PRX Quantum* **2**, 010319 (2021).

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