Entanglement witnessing in ultracold atoms via the Wehrl entropy

Oliver Stockdale,[1,*] Tobi Haas,[2] and Martin Gärttner[1,2]

[1] *Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany*

[2] *Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany*

We develop a theoretical framework to witness entanglement in spinor Bose gases using entropic uncertainty relations. Simultaneous measurements of two non-commuting spin observables (here $\hat{S}_x$ and $\hat{Q}_{yz}$) allows for direct access to a quasi-probability distribution [Fig. 1(b)] and its associated entropy. In the Gaussian regime this corresponds to the Husimi distribution and Wehrl entropy, respectively. We simulate the system via the truncated Wigner approximation and perform a covariance analysis of the distribution [Fig. 1(c)]. We observe a non-zero Wehrl mutual information I_W [Fig. 1(d)], where $I_W > 0$ is a perfect entanglement witness as it measures only the quantum correlations (given the initial state has zero classical correlations). Future work will extend the analysis to the non-Gaussian regime to understand the long-time behaviour of entanglement.

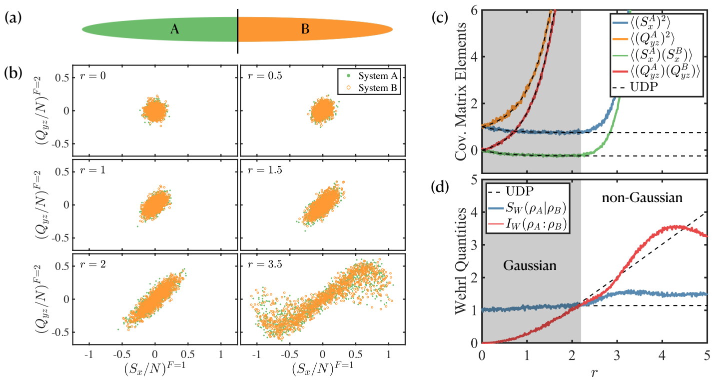

FIG. 1. (a) A one-dimensional condensate is split into subsystem A and B. (b) Phase space distributions of the subsystems for different squeezing parameters $r \propto t$. (c) Numerical simulations (colour) compared to analytical calculations (UDP) of covariance matrix elements. (d) Wehrl conditional entropy S_W and mutual information I_W (lower). Shading represents whether the system is in the Gaussian regime.

* oliver.stockdale@kip.uni-heidelberg.de