

Detection of non-locality in a Bose-Einstein condensate

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The results of measurements performed on several quantum systems can exhibit correlations with no classical explanation. These so-called non-local correlations are revealed through the violation of a Bell inequality and form an important resource for quantum technology. While non-locality has been demonstrated in few-particle systems, its role in many-body quantum systems is much less understood. A recent theory paper shows that in a many-body system, non-locality can be revealed by single- and two-particle correlations only [1]. Based on this, we introduce and experimentally implement a technique to detect non-locality in spin-squeezed states of a two-component Bose-Einstein condensate [2]. From measurements of first and second moments of the collective atomic spin along several axes, we construct an inequality whose violation signals non-locality. The inequality can be connected to a non-locality witness that is stricter than the Wineland spin-squeezing parameter, emphasizing that entanglement is necessary but not sufficient for non-locality. Our experiments reveal non-locality in spin-squeezed Bose-Einstein condensates of several hundred atoms.

- [1] J. Tura, R. Augusiak, A.B. Sainz, T. Vértesi, M. Lewenstein, A. Acín, *Science* 344, 1256 (2014)
- [2] M.F. Riedel, P. Böhi, Y. Li, T.W. Hänsch, A. Sinatra, P. Treutlein, *Nature* 464, 1170 (2010)