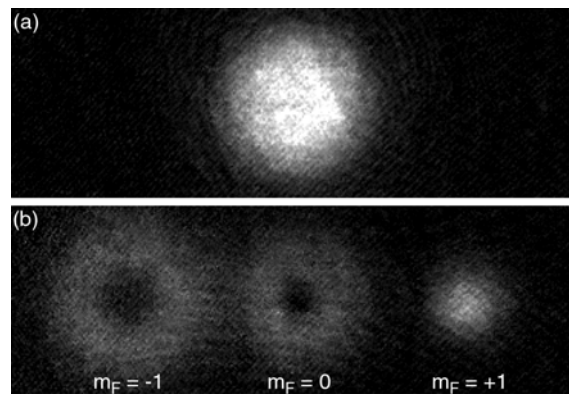


## Coreless vortex formation in a spinor Bose-Einstein condensate

Topological defects vary between superfluid systems described by scalar and vector order parameters. In spin-less or spin-polarized condensates, line defects such as vortices have cores where the density of condensed particles is necessarily zero to keep the order parameter single-valued. However, in condensates with an internal, spin degree-of-freedom, coreless vortices exist as spin textures.

We have phase-imprinted coreless vortices in a spinor Bose-Einstein condensate [1] following a recent theoretical suggestion [2]. The three-component order parameter of  $F = 1$  sodium condensates held in a magnetic trap was manipulated by adiabatically reducing the magnetic bias field along the trap axis to zero. The remaining field was a radial quadrupole field. This distributed the condensate population across its three spin states and created a spin texture. Each spin state acquired a different phase winding which caused the spin components to separate radially.



Coreless vortex formation in a spinor Bose-Einstein condensate. Coreless vortices were imprinted by slowly ramping the bias field to zero, and diagnosed by suddenly switching on a strong bias field, which decomposed the wavefunction into its  $m_F$  components with respect to a fixed axis. Axial absorption images display the optical density of condensates after 20 ms of ballistic expansion (a) without and (b) with a magnetic field gradient applied to separate the three different spin states. The ring-shaped structures for the  $m_F = -1$  and  $0$  states are evidence for the non-zero winding number (or angular momentum). The field of view is  $1.0 \text{ mm} \times 3.0 \text{ mm}$ .

1. A.E. Leanhardt, Y. Shin, D. Kielpinski, D.E. Pritchard, and W. Ketterle, *Coreless vortex formation in a spinor Bose-Einstein condensate*, Phys. Rev. Lett. **90**, 140403 (2003).
2. T. Isoshima, M. Nakahara, T. Ohmi, and K. Machida, *Creation of a persistent current and vortex in a Bose-Einstein condensate of alkali-metal atoms*, Phys. Rev. A **61**, 063610 (2000).