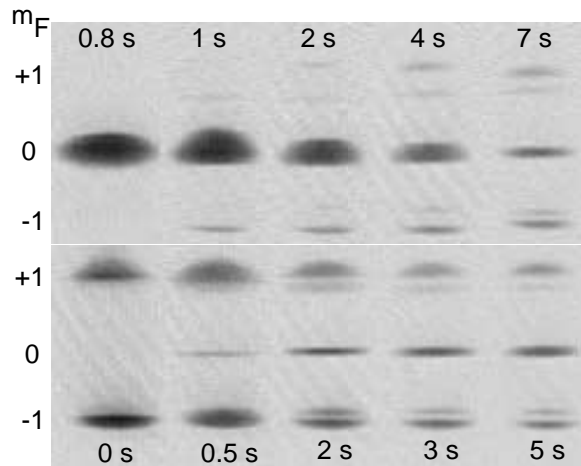


Spinor Bose-Einstein condensates in optical traps

We have studied the equilibrium state of spinor condensates in an optical trap [1]. In contrast to magnetically trapped condensates, spinor condensates have the orientation of the spin as a degree of freedom, which can be described by a multi-component wavefunction (one for each magnetic sublevel). In an $F=1$ spinor condensate subject to spin relaxation, two $m_F=0$ atoms can collide and produce a $m_F=1$ and a $m_F=-1$ atom and vice versa. The most dramatic effect was seen when we started with a condensate in a pure $m_F=0$ state. Depending on the external magnetic field, the formation of three domains of $m_F = +1, 0, -1$ atoms was observed.

The figure shows a sequence of images with different dwell times in the optical trap. Starting with either the pure $m_F=0$ component (upper series) or with a 50-50 mixture of the $m_F = \pm 1$ components (lower series), the same equilibrium distribution was reached.

Comparison of such equilibrium distributions to a theoretical model revealed that the spin-dependent interaction $c\vec{F}_1 \cdot \vec{F}_2$ between two sodium atoms in the $F=1$ state is anti-ferromagnetic (i.e. $c>0$). Furthermore, the experimental results showed clear evidence for the miscibility of $m_F = -1$ and $m_F = +1$ components and the immiscibility of $m_F = \pm 1$ and $m_F = 0$. This opens the possibility for detailed studies of miscible and immiscible multi-component condensates.



Absorption images of spinor condensates released from the optical trap, after 25 ms of ballistic expansion. The different m_F states were separated by an axial field gradient (Stern-Gerlach filter). The images taken after various dwell times in the trap show how the atoms evolved into the same equilibrium distribution although they were initially prepared in a pure $m_F = 0$ state (upper row) or in equally populated $m_F = \pm 1$ states (lower row). The height of the images is 2.7 mm.

1. J. Stenger, S. Inouye, D.M. Stamper-Kurn, H.-J. Miesner, A.P. Chikkatur, and W. Ketterle, *Nature* **396**, 345 (1998).