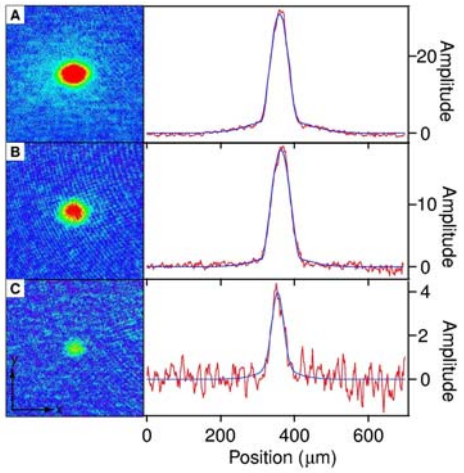
Cooling of Bose-Einstein condensates below 500 Picokelvin

The lowest temperatures for trapped atoms are usually achieved in low-density samples. At high densities, interaction effects adversely affect the cooling process and the temperature diagnostics. We have achieved a new record-low temperature of less than 500 picokelvin in a very weak trap using a combination of gravitational and magnetic forces [1]. The partially condensed atomic vapors were adiabatically decompressed by weakening the gravito-magnetic trap to a mean frequency of 1 Hertz, then evaporatively reduced in size to 2500 atoms. This lowered the peak condensate density to 5 x 10^{10} atoms per cubic centimeter and cooled the entire cloud in all three dimensions to a kinetic temperature of 450 ± 80 picokelvin.

These samples are characterized by a thermal velocity of 1 mm/s, a speed of sound of 100 μm/s, and a healing length limited by the 20 μm harmonic oscillator length of the trapping potential. Low temperature and low-density ensembles are important for spectroscopy, metrology, and atom optics. In addition, they are predicted to experience quantum reflection from material surfaces.



Picokelvin temperature thermometry. Partially condensed atomic vapors confined in the gravito-magnetic trap with (A) 28,000, (B) 16,000, and (C) 2,500 atoms. The one-dimensional cross sections (red) were obtained by integrating the two-dimensional absorption images of the trapped clouds along the y-axis. Bimodal fits (blue) yielded temperatures of (A) 1.05 ± 0.08 nK, (B) 780 ± 50 pK, and (C) 450 ± 80 pK, where the uncertainty is due to the fit of an individual image. The field of view for the absorption images in (A) to (C) is 460 μm x 460 μm.

1. A.E. Leanhardt, T.A. Pasquini, M. Saba, A. Schirotzek, Y. Shin, D. Kielpinski, D.E. Pritchard, and W. Ketterle, *Cooling of Bose-Einstein condensates below 500 Picokelvin*, Science **301**, 1513 (2003).