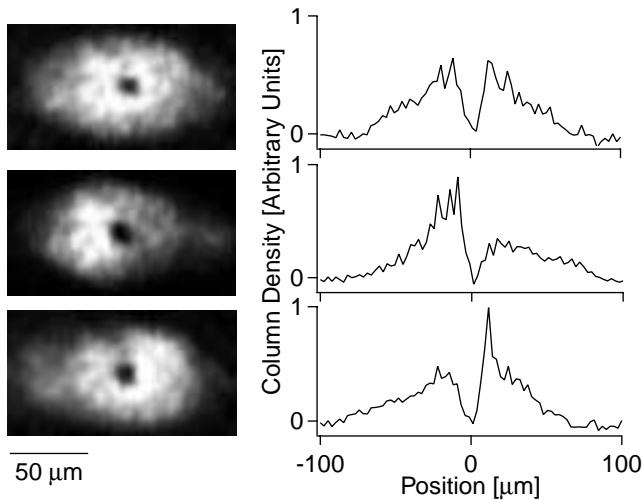


Dissipationless flow and superfluidity in gaseous Bose-Einstein condensates

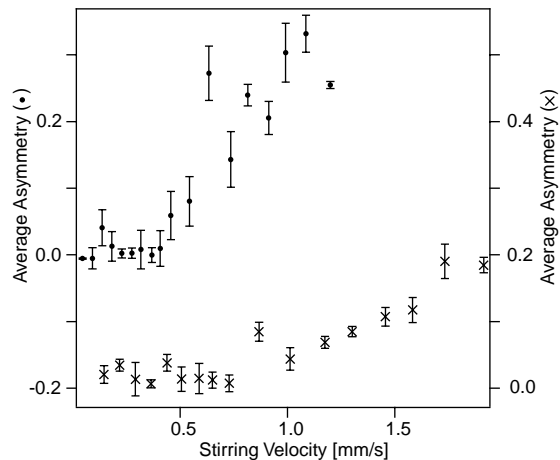
In previous work [1] we found evidence for a critical velocity in a condensate. The Bose-Einstein condensate was stirred with a laser beam at variable velocity, and the onset of dissipation was observed by monitoring the temperature of the sample. We have studied the same system by observing the condensate during the stirring using repeated *in situ* non-destructive imaging of the condensate. These images show the distortion of the density distribution around the moving object, thus directly probing the dynamics of the flow field [2].



Pressure difference across a laser beam moving through a condensate. On the left side *in situ* phase contrast images of the condensate are shown, strobed at each stirring half period: beam at rest (top); beam moving to the left (middle) and to the right (bottom). The profiles on the right are horizontal cuts through the center of the images. The stirring velocity and the maximum sound velocity were 3.0 mm/s and 6.5 mm/s, respectively.

The distortion or asymmetry of the flow is proportional to the drag force and a sensitive indicator for dissipation. The onset of dissipation was found at a critical velocity of about 10 % of the speed of sound which corrects the higher value found previously with a less sensitive method [1]. A comparison of the new technique observing the drag force to the calorimetric method showed good agreement.

Density dependence of the critical velocity. The onset of the drag force is shown for two different condensate densities, corresponding to maximum sound velocities of 4.8 mm/s (solid circles, left axis) and 7.0 mm/s (crosses, right axis). The stirring amplitudes are 29 μm and 58 μm , respectively. The two vertical axes are offset for clarity. The bars represent statistical errors.



1. C. Raman, M. Köhl, R. Onofrio, D.S. Durfee, C.E. Kulewicz, Z. Hadzibabic, and W. Ketterle, Phys. Rev. Lett. **83**, 2502 (1999).
2. R. Onofrio, C. Raman, J.M. Vogels, J. Abo-Shaeer, A.P. Chikkatur, and W. Ketterle, Phys. Rev. Lett. **85**, 2228 (2000).