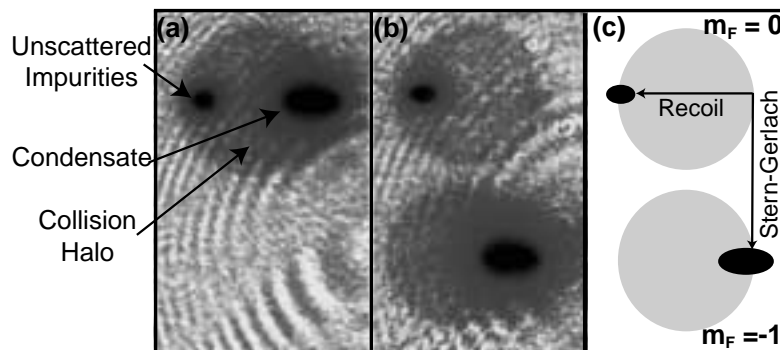


Superfluid suppression of impurity scattering in a Bose-Einstein condensate

The concept of superfluidity applies to both macroscopic and microscopic objects. In both cases, there is no dissipation or drag force as long as the objects move with a velocity less than the so-called critical velocity. A moving macroscopic object creates a complicated flow field. Above a certain velocity, vortices are created. In contrast, the physics of moving impurities, which are microscopic objects, is much simpler. At velocities larger than the Landau critical velocity, they will create elementary excitations, phonons or rotons in the case of liquid helium-4.

We could create impurity atoms in a trapped BEC by transferring some of the atoms into another hyperfine state using an optical Raman transition. The photon recoil and therefore the velocity of the impurity atoms was varied by the angle between the two laser beams. Collisions between the impurity atoms and the condensate were observed as a redistribution of momentum when the velocity distribution was analyzed with a ballistic expansion technique. The collisional cross section was dramatically reduced when the velocity of the impurities was reduced below the speed of sound of the condensate, in agreement with the Landau criterion for superfluidity [1].



Observation of collisions between the condensate and impurities. The impurities in the $m=0$ hyperfine state traveled at 6 cm/s to the left. Collisions redistribute the momentum over a sphere in momentum space, resulting in the observed halo (a). In figure (b), the impurities and the condensate in the $m=-1$ state were separated with a magnetic field gradient during the ballistic expansion. The effect of collisions is to slow down some of the impurity atoms and speed up the condensate atoms. The absorption images are 4.5 mm times 7.2 mm in size.

1. A.P. Chikkatur, A. Görlitz, D.M. Stamper-Kurn, S. Inouye, S. Gupta, and W. Ketterle, Phys. Rev. Lett. **85**, 483 (2000).