One-dimensional bosons and Fermions in Optical traps.

Authors: B. Paredes, Nature 429, 277 (2004); M. Kohl et al. ArXiv.org/cond-mat/0406397 (and T. Stoferle et al. PRL 92 130403 (2004)); T. Kinoshita, T. Wenger and D.S. Weiss Science 2004 0:11007001-0.

Recommended and a commentary by Thierry Giamarchi, University of Geneva.

The effect of interactions on superfluidity has always been a challenging question. This is specially true in one dimension where particles cannot exchange each other without feeling the interactions and it is thus impossible to disentangle interactions and statistics. One dimensional bosons thus behave in a very special way. For zero interactions they behave as true bosons and would like to condense in the lowest momentum. For an infinite local repulsion among the bosons, the bosons cannot pass but are free particles on different sites, and thus behave very closely to spinless fermions. Such an impenetrable gas of bosons is known as the Tonks-Girardeau gas, and is of course quite different from a simple Bose condensate. In fact for a delta function repulsion a full solution of the problem has been given by Lieb and Liniger, showing indeed the evolution of the momentum distribution. More recently Haldane has shown that interacting bosons are, just like interacting fermions, a Luttinger liquid in one dimension. It is important to note that although in the Tonks-Girardeau limit of infinite repulsion the bosons share some aspects of spinless fermions, they also show important differences. In particular the single particle Green's function decays, with space and time, quite differently than that of free fermions.

Cold atoms in optical lattices have provided a very clean system to realize one dimensional bosons. Pushing such system to the strongly correlated limit has been an important challenge. Recently various experimental groups have succeeded in achieving the strongly correlated limit, using either an optical trap and the proximity to a Mott transition or staying in the continuum. Clearly more work is needed to bridge the gap between theory and experiment, while taking into account the various inherent complications of the experimental systems. But realizing such an hybrid state between true fermions and true bosons, opens already many possibilities. One of them, already under investigation with cold atoms, is the coupling of such systems.