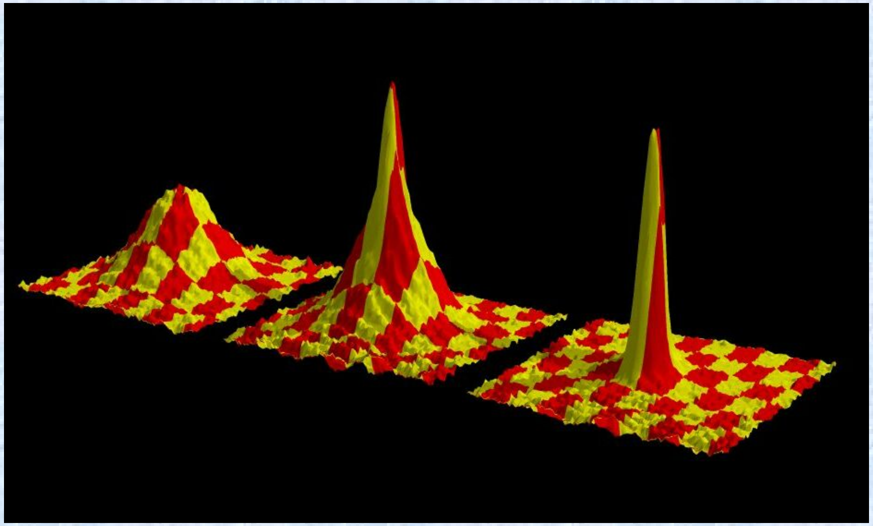
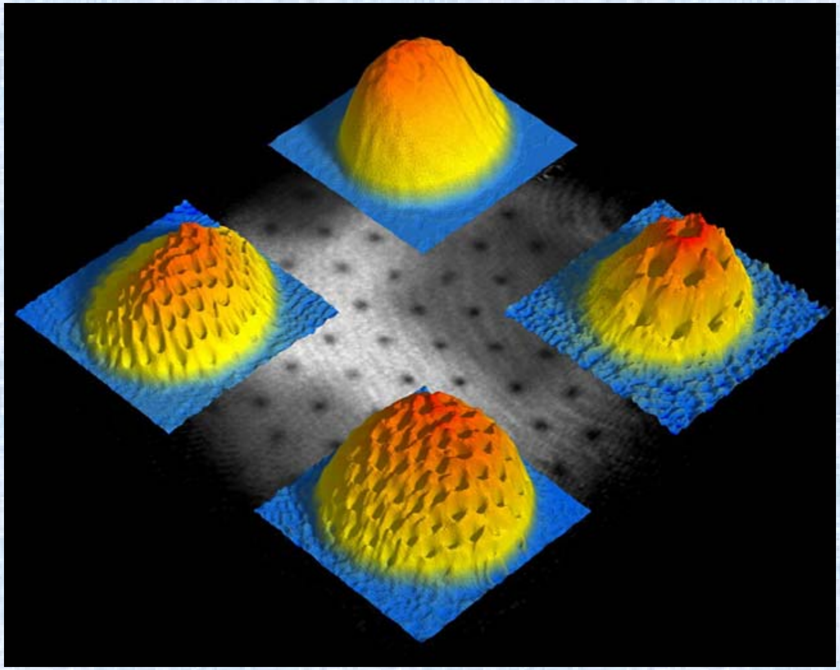
Trapped ultracold atoms: Bosons

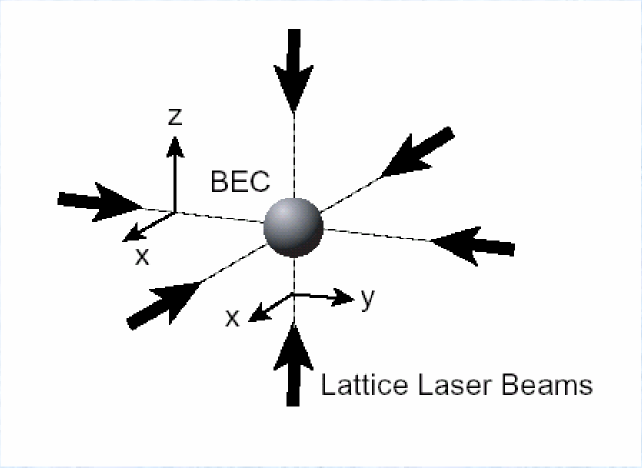


Bose-Einstein condensation of a dilute bosonic gas



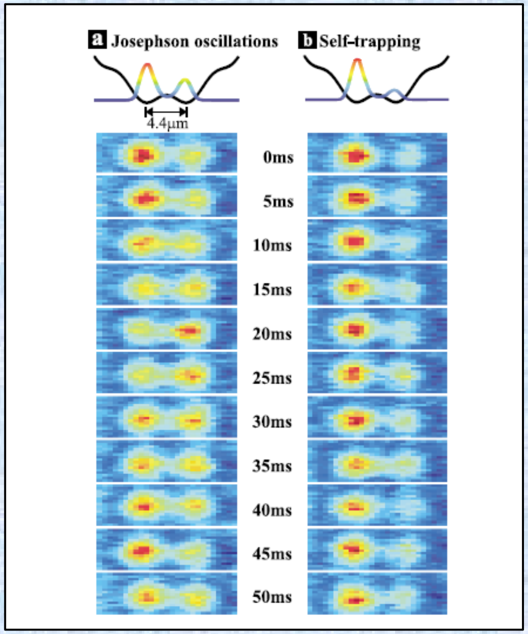
Probe of superfluidity: vortices

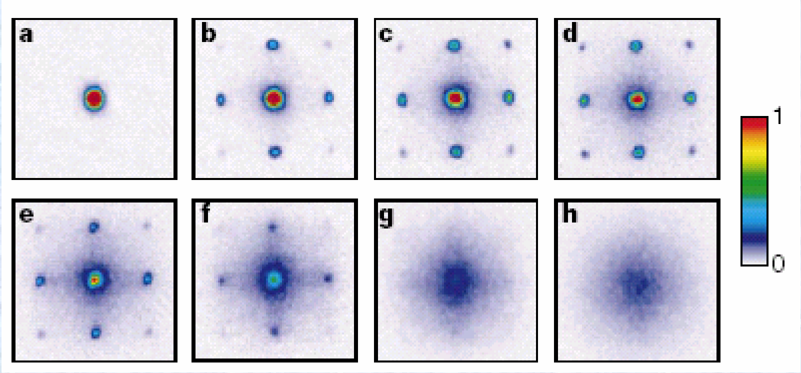
Ultracold bosons in an optical lattice



$$V_{ext}(\vec{r}) = V\left(\sin^2(kx) + \sin^2(ky) + \sin^2(kz)\right)$$

A double well





Increasing V, one passes from a superfluid to a Mott insulator

Trapped ultracold atoms: Fermions

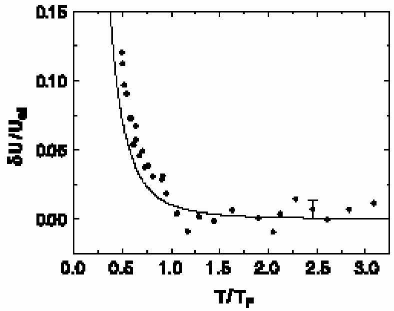
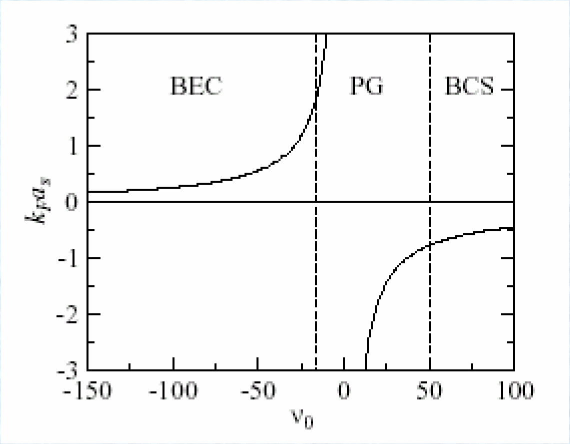


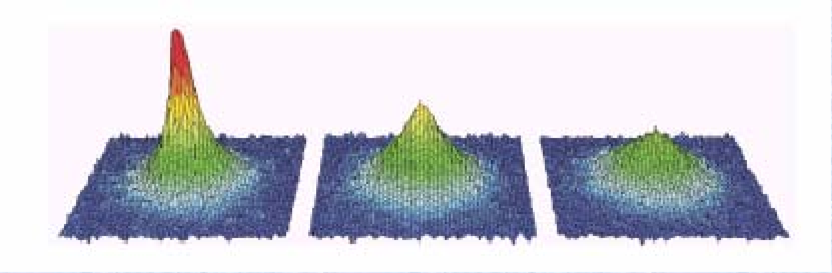
Fig. 4. Emergence of quantum degeneracy as seen in the energy of the trapped Fermi gas. A moment analysis was used to extract the energy of the gas from time-of-flight absorption images. The excess energy $\delta U = U - U_{cl}$ is shown versus T/T_F, where U is the measured energy and $U_{cl} = 3Nk_BT$ is the energy of a classical gas at the same temperature. Each point represents the average of two points from the evaporation trajectory shown in the main part of Fig. 3, and the single error bar shows the typical statistical uncertainty. The measured excess energy at low T/T_F agrees well with thermodynamic theory for a noninteracting Fermi gas (line).

A non-interacting Fermi gas

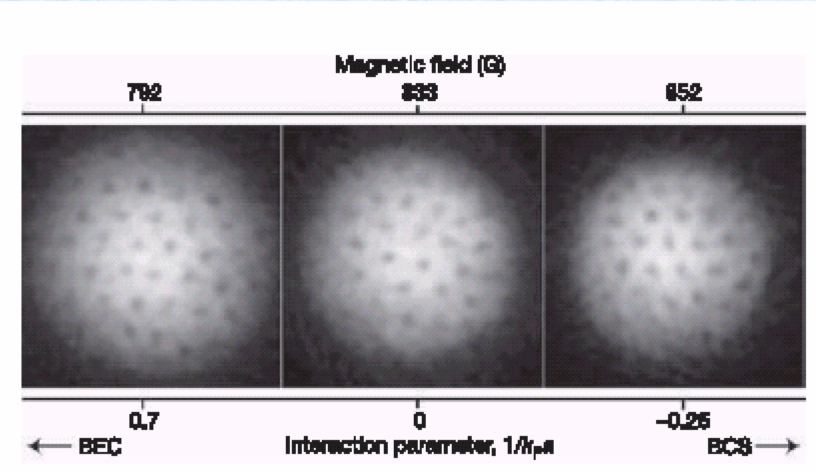


Tuning the interactions…

… and inducing a fermionic “condensate”



Probing the superfluidity for fermionic gases



Close to the crossover ...

... and in a lattice

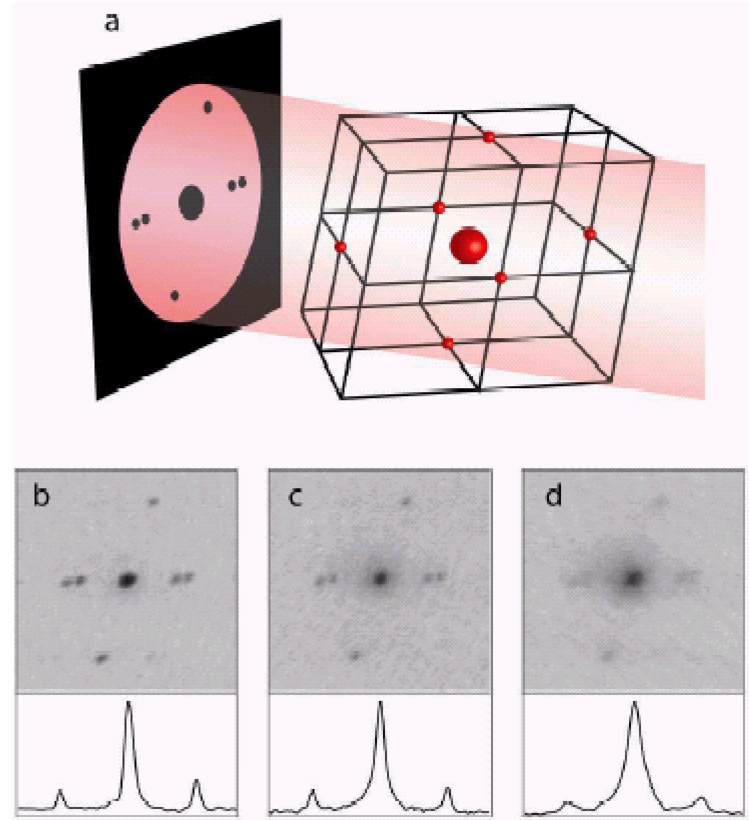
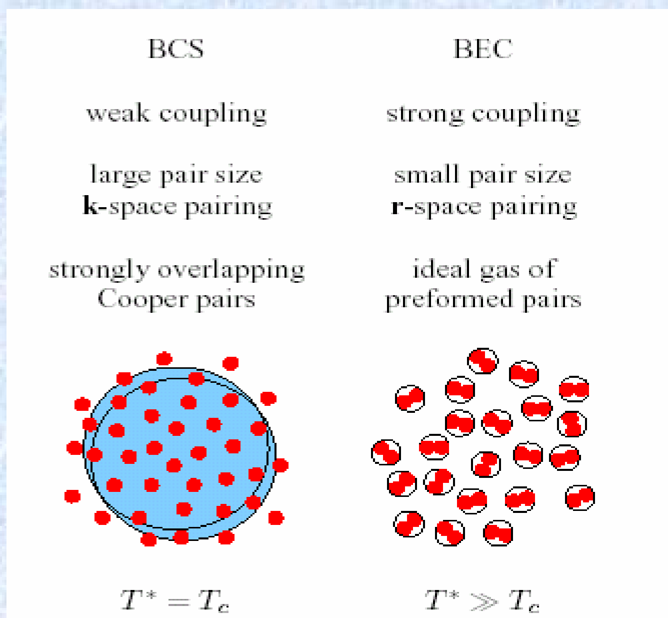


FIG. 1: Observation of high contrast interference of fermion pairs released from an optical lattice below and above the Feshbach resonance. (a) shows the orientation of the reciprocal lattice, also with respect to the imaging light. Interference peaks are observed for magnetic fields of (b) 822 G, (c) 867 G and (d) 917 G. Lattice depth for all images is 5 E_r and each image is the average of 3 shots, taken after 6.5 ms ballistic expansion. Field of view is 1 mm by 1 mm. Density profiles through the vertical interference peaks are shown for each image.

More on the BCS-BEC crossover



Trapped ultracold atoms

Ultracold bosons and/or fermions in trapping potentials provide new experimentally realizable <u>interacting</u> systems on which to test well-known paradigms of the statistical mechanics:

-) in a periodic potential -> strongly interacting lattice systems

-) interaction can be enhanced/tuned through Feshbach resonances

(BEC-BCS crossover – unitary limit)

-) inhomogeneity can be tailored – defects/impurities can be added

-) effects of the nonlinear interactions on the dynamics

-) strong analogies with superconducting and superfluid systems

-) quantum coherence / superfluidity on a mesoscopic scale

-) quantum vs finite temperature physics

-) needed a theory for mesoscopic open systems

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