Quantum vortices and the quantum mechanics of two-dimensional superfluids

Abstract:

We describe the localization transition of superfluids on two- dimensional lattices into commensurate Mott insulators with average particle density p/q (p, q relatively prime integers) per lattice site. For bosons on the square lattice, we use a dual description and argue that the superfluid has at least q degenerate species of vortices which transform under a projective representation of the square lattice space group. The formation of a single vortex condensate produces the Mott insulator, which is required by the projective space group to have density wave order; such a second-order transition is forbidden in the Landau-Ginzburg-Wilson framework.

We argue that our results apply essentially unchanged to electronic systems with short-range pairing and give a natural explanation of recent scanning tunneling microscopy measurements on the vortex lattice of BSCCO which exhibits halos in the vicinity of each vortex with modulations in the tunneling conductance at a period close to 4 lattice spacings. Our interpretation implies that the size of the halos is determined by the zero-point fluctuations of the quantum vortices. We will show how existing scanning tunneling microscopy measurements lead to a quantitative estimate of the vortex inertial mass.