Title:Quantized vortex in an atomic Bose-Einstein condensate at Dirac point for honeycomb lattice

Abstract: Ultracold atomic systems provide an ideal experimental platform for investigating spin-orbit coupling and topological quantum states. Given the absence of significant intrinsic spin-orbit coupling in ultracold atoms, experimental approaches typically rely on artificial construction through Raman laser coupling or gradient magnetic fields. In a graphene-like honeycomb optical lattice, we discovered that when atoms are positioned near the Dirac points of the energy band, the non-commutativity between the harmonic oscillator potential and the pseudospin degree of freedom naturally induces spin-orbit coupling. Leveraging this emergent mechanism, we have, for the first time, directly observed quantized vortices in momentum space. By modulating the depth of the optical lattice and the strength of the confining potential, we further achieved quantum phase transitions between the superfluid phase, vortex superfluid phase, and Mott insulator phase. This research elucidates the intrinsic relationship between spin-orbit coupling and the topological structure of momentum space, thereby opening new experimental avenues for exploring novel topological quantum states.