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Symmetry Breaking Effects of Instantons in Parton Gauge Theories

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Transitions between fractionalized and conventional quantum phases of matter in 2+1 dimensions are conceptually best understood within the framework of parton gauge theories, whereby the confinement of fractionalized excitations and spontaneous breaking of global symmetries in conventional phases is argued to result from the proliferation of gauge monopoles/instantons. To complement recent studies of the quantum numbers and scaling dimensions of monopole operators in parton gauge theories of frustrated quantum antiferromagnets, we provide an explicit semiclassical derivation of instanton contributions to the low-energy effective parton gauge theory for hardcore bosons on the honeycomb lattice using methods originally developed by 't Hooft in the solution of the U(1) problem in quantum chromodynamics. While the symmetry-breaking effect of instantons is typically associated with massless fermions and the Atiyah-Singer index theorem on compact manifolds, we show that the spontaneous breaking of the U(1) boson number conservation symmetry in the superfluid phase results here from Euclidean zero modes of massive Dirac fermions bound to instantons in noncompact spacetime.

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