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Theory of Nematic Fractional Quantum Hall State

YIZHI YOU, University of Illinois Urbana-Champaign

Rotation symmetry can be spontaneously broken in the background of fractional quantum Hall fluids. The resulting nematic state is characterized by an order parameter that represents these quadrupolar fluctuations, which play the role of fluctuations of the local geometry of the quantum fluid. We demonstrate that the low-energy effective theory of the nematic order parameter has z=2 dynamical scaling exponent, due to a Berry phase term of the order parameter, which is related to the nondissipative Hall viscosity. By investigating the spectrum of collective excitations, we demonstrate that the mass gap of the Girvin-MacDonald-Platzman mode collapses at the isotropic-nematic quantum phase transition. An interesting feature of the nematic phase is that it has topological defects known as disclinations that act as local center of spatial curvature for the electronic degrees of freedom. The effective field theory provides a full description of the response of the quantum fluid to external electromagnetic probes and to local deformations of the underlying crystal. Although the theory is specific for fractional quantum Hall states, these ideas and mechanisms are of general interest to understanding the behavior of geometric fluctuations in other topological phases in condensed matter, including half-filled Landau Level and Chern insulators.