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Edge Channels of Quantum Hall States in Graphene probed by Atomic Force Microscopy

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The quantum Hall (QH) effect, a topologically non-trivial quantum phase, expanded and brought into focus the concept of topological order in physics. The bulk topology is closely related to the properties of edge states that are of crucial importance to the QH effect. The QH edge states in graphene take on an even richer role as graphene is distinguished by its four-fold nearly-degenerate zero energy Landau level (zLL). The symmetry of zLL is broken by minute lattice-scale potentials enhanced by electron interactions. A particular symmetry of ground state is associated with the distinct dispersion of edge states, however the spatial dispersion has been measured with limited success. In this report, we map the quantum Hall broken-symmetry edge states comprising the graphene zLL at integer filling factors 0 and 1 across the quantum Hall edge boundary using atomic force microscopy (AFM). Measurements of the chemical potential resolve the energies of the four-fold degenerate zLL as a function of magnetic field. This dependence suggests an interplay of the moiré superlattice potential of the graphene/boron nitride system and spin/valley symmetry-breaking effects.