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Chiral symmetry breaking and the quantum Hall effect in monolayer graphene

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When graphene is placed in a strong magnetic field it exhibits quantum Hall states at fillings that can be predicted by taking into account the relativistic form of the low-energy electronic excitations and ignoring interactions between electrons. However, additional quantum Hall states are observed at filling fractions $\nu = 0$ and $\nu = \pm 1$ that are not explained within a picture of non-interacting electrons. We propose that these states arise from interaction induced chiral symmetry breaking orders. We argue that when the chemical potential is at the Dirac point, weak onsite repulsion supports an easy-plane antiferromagnet state, which simultaneously gives rise to ferromagnetism oriented parallel to the magnetic field direction, whereas for $|\nu|$=1 easy-axis antiferromagnetism and charge-density-wave order coexist. We perform self-consistent calculations of the magnetic field dependence of the activation gap for the $\nu = 0$ and $\nu = 1$ states and obtain excellent agreement with recent experimental results.

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Reference: B. Roy, M. P. Kennett, and S. Das Sarma, Phys. Rev. B **90**, 201409(R) (2014).

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