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Direct observation of Landau levels of massless and massive Dirac fermions.[1] GUOHONG LI, EVA Y. ANDREI, Dept. of Physics Rutgers University , Piscataway NJ — The low energy quasiparticles in graphene resemble massless relativistic particles (Dirac fermions): they have a linear energy-momentum spectrum and possess internal degrees of freedom arising from the crystal symmetry of the honeycomb lattice, leading to particle anti-particle pairs. When two layers of graphene are coupled together, the quasiparticles acquire a band-mass and are transformed into chiral massive fermions. Both types of quasiparticles develop unusual Landau levels in a magnetic field which profoundly alter the magneto-transport properties. We will report the direct observation of the Landau levels associated with these quasiparticles using a low temperature STM in fields up to 12 Tesla. The experiments reveal two independent sequences of Landau levels that provide evidence for the coexistence of massless and massive Dirac fermions. The energy levels of the former exhibit a square-root dependence on both field and Landau-level index n, while the latter are linear in field with a Landau-level index dependence of $[n(n+1)]^{1/2}$. Both sequences exhibit a zero energy Landau level which is a unique and direct consequence of the quantum-relativistic nature of these quasiparticles.

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