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Self-similar occurrence of massless Dirac particles in graphene under magnetic field JUN-WON RHIM, KWON PARK, Korea Institute for Advanced Study — Intricate interplay between the periodicity of the lattice structure and that of the cyclotron motion gives rise to a well-known self-similar fractal structure of the Hofstadter butterfly for an electron moving in lattice under magnetic field. Evolving from the $n = 0$ Landau level, the central band of the Hofstadter butterfly is especially interesting since it may hold a key to the mysteries of the fractional quantum Hall effect in graphene. In this paper, we develop an effective Hamiltonian method that can be used to provide an accurate analytic description of the central Hofstadter band in the weak-field regime. One of the most important discoveries obtained in this work is that massless Dirac particles always exist inside the central Hofstadter band no matter how small the magnetic flux may become. In other words, with its bandwidth broadened by the lattice effect, the $n = 0$ Landau level contains massless Dirac particles within itself. In fact, by carefully analyzing the self-similar recursive pattern of the central Hofstadter band, we conclude that massless Dirac particles should occur under arbitrary magnetic field. As a corollary, the central Hofstadter band also contains a self-similar structure of recursive Landau levels associated with such massless Dirac particles.

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