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Coexisting massive and massless Dirac fermions in symmetry-broken bilayer graphene

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Charge carriers in bilayer graphene are widely believed to be massive Dirac fermions that have a bandgap tunable by a transverse electric field. However, a full transport gap, despite its importance for device applications, has not been clearly observed in gated bilayer graphene, a long-standing puzzle. Moreover, the low-energy electronic structure of bilayer graphene is widely held to be unstable towards symmetry breaking either by structural distortions, such as twist, strain, or electronic interactions that can lead to various ground states. Which effect dominates the physics at low energies is hotly debated. We find by direct band-structure measurements and by calculations that a native imperfection of bilayer graphene, a distribution of twists whose size is as small as $\sim 0.1°$, is sufficient to generate a completely new electronic spectrum consisting of massive and massless Dirac fermions. The massless spectrum is robust against strong electric fields, and has a unusual topology in momentum space consisting of closed arcs having an exotic chiral pseudospin texture, which can be tuned by varying the charge density. The discovery of this unusual Dirac spectrum may be widely relevant to charge transport in bilayer graphene.