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Exotic Dirac Wavepackets Accumulating Aharonov-Bohm-type Phase in Free Space IDO KAMINER, JONATHAN NEMIROVSKY, MIKAEL RECHTSMAN, RIVKA BEKENSTEIN, MORDECHAI SEGEV, Physics Department - Technion — Following the seminal 1958 paper by Aharonov-Bohm (AB), it is expected that two parts of the wavefunction of an electron can accumulate phase difference even when they are confined to a region in space with zero EM field. The AB effect was groundbreaking: the EM vector potential is a physical quantity affecting the outcome of experiments directly, not only through the fields extracted from it. But is the EM potential a real necessity for an AB-type effect? Can such effect exist in a potential-free system such as **free-space**? Here, we find self-accelerating solutions of the potential-free Dirac equation, for massive/massless fermions/bosons. These exotic Dirac particles mimic the dynamics of a free-charge moving under a "virtual" EM field. They accelerate even though no field is acting on them (and no charge is defined): the entire dynamics is a direct result of the initial conditions. We show that such particles display an **effective AB effect** that can be explained by a "virtual" potential that "causes" the exact same acceleration. We prove that one can create all effects induced by EM fields by only controlling the initial conditions of a wave pattern. Altogether, measurements taken along the trajectory cannot distinguish between a real force and this virtual force: self-induced by the wavepacket itself. The measurable effects of this virtual force are real by all measurable quantities. These phenomena can be observed in various settings: e.g., optical waves in hyperbolic metamaterials, and matter waves in honeycomb interference structures.

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