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Wigner localization in a graphene quantum dot with a mass gap

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— The role of electron-electron interactions in graphene is an open issue that impacts on the operation of quantum dots (QDs) and other graphene-based devices. Whereas electrons in bulk graphene allegedly behave as noninteracting particles except for subtle effects, there is strong evidence that electrons in carbon-based nanostructures–nanotubes–form Wigner molecules [Nat. Phys. 9, 576 (2013)]. Besides, a significant effort is presently devoted to minimize the role of disorder in next-generation graphene QDs. Here we show theoretically that Dirac electrons in a clean, circular graphene QD with a mass gap induced by the breaking of sublattice symmetry form a Wigner molecule for realistic values of device parameters. The evidence is the combined analysis of many-body energies, one-body densities, and pair correlation functions obtained through the exact diagonalization of the interacting Dirac-Weyl Hamiltonian. This method, which uses two different sublattice envelopes and includes both inequivalent Dirac cones, allows us to take all many-body correlations into account. The experimental signature of Wigner localization is the suppression of the fourfold periodicity of the filling sequence and the quenching of excitation energies, accessible through Coulomb blockade spectroscopy.

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