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Symmetry and Dirac points in graphene spectrum

Abstract

Many exciting physical properties of graphene can be traced to the presence of conical singularities ("Dirac points") in its dispersion relation. Calculations in the physics literature (e.g. Wallace (1947)) are done within the tight-binding approximation — essentially, a discrete Schroedinger operator on a graph consisting of two vertices. More recently, Kuchment and Post (2007) studied quantum graphs arranged to resemble graphene (honeycomb) structure. Grushin (2009) considered the Schrödinger in R^2 with a weak potential symmetric with respect to the honeycomb lattice; Fefferman and Weinstein (2012) proved the presence of Dirac points for a generic potential with this symmetry.

We will present general yet very simple proofs that work in all the above models: R^2, discrete and quantum graph Schroedinger operators. The following three results will be presented: (a) existence of the degeneracies — this is established by showing that the relevant operator decomposes into a direct sum of three parts, two of which are isospectral, (b) conical nature of the dispersion relation around the degeneracies — which is a consequence of the symmetries of the dispersion relation, and (c) stability of Dirac points under the perturbation — proved using the Berry phase, illustrated by animations.

The talk is based on joint work with Andrew Comech, arXiv:1412.8096