MAS17-2017-000056

Abstract for an Invited Paper
for the MAS17 Meeting of
the American Physical Society

Zero-energy vortices in two-dimensional Dirac semimetals[1]

MIKHAIL PORTNOI, University of Exeter, UK

Contrary to a widespread belief, full electrostatic confinement is possible for Dirac-Weyl fermions with linear dispersion in gapless 2D systems such as graphene, surface states on the surface of topological insulators and gapless HgTe quantum wells. The confinement is possible precisely at the Dirac point where the particles pseudospin is ill-defined, and these bound states must possess non-zero angular momentum (vorticity). Formation of fully-confined zero-energy vortices provides an alternative explanation for various STM experiments in graphene. We also show that a pair of two-dimensional massless Dirac-Weyl fermions can form a bound state independently on the sign of the inter-particle interaction potential, as long as this potential decays at large distances faster than Kepler's inverse distance law. The coupling occurs only at the Dirac point, when the charge carriers lose their chirality. These two-particle states must have a non-zero internal angular momentum, meaning that they only exist as stationary vortices. This leads to the emergence of a new type of energetically-favourable quasiparticles: double-charged zero-energy vortices. Their bosonic nature allows condensation and gives rise to Majorana physics without invoking a superconductor. The presence of dark-matter-like silent immobile vortices explains a range of poorly understood experiments in gated graphene structures at low doping.

[1]This work was supported by the EU H2020 RISE project CoExAN (Grant No. H2020-644076), EU FP7 ITN NOTEDEV (Grant No. FP7-607521), FP7 IRSES projects CANTOR (Grant No. FP7-612285) and InterNoM (Grant No. FP7-612624), and UK EPSRC.