Majorana Zero Modes in Graphene

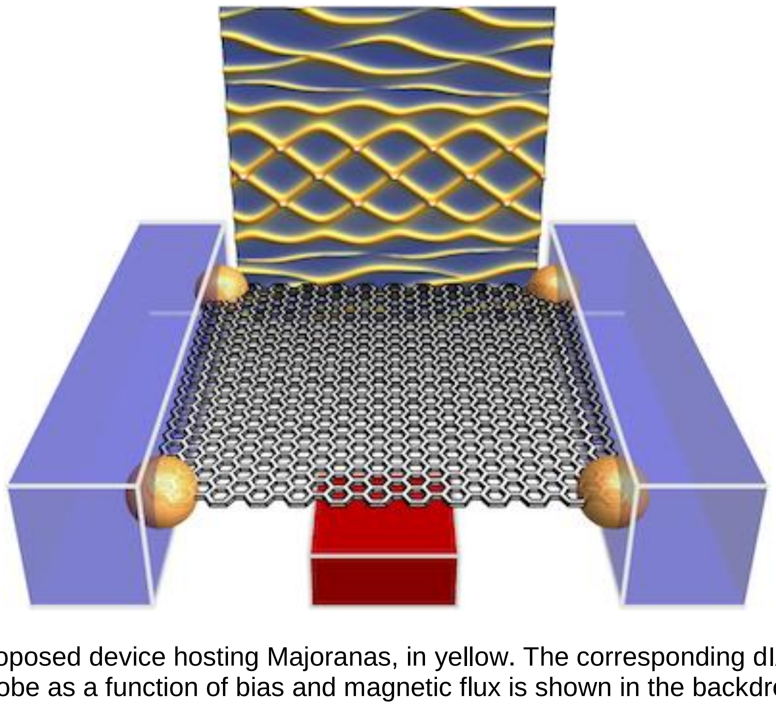
P. San-Jose[(1)], J. L. Lado[(1)], R. Aguado[(2)],F. Guinea[(3,4)], J. Fernández-Rossier[(2,5)]

(1) Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas (ICMM-CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain
(2) International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga, 4715-330 Braga, Portugal
(3) Instituto Madrileño de Estudios Avanzados en Nanociencia (IMDEA-Nanociencia), 28049 Madrid, Spain
(4) Department of Physics and Astronomy, University of Manchester, Manchester M13 9PL, UK
(5) Departamento de Física Aplicada, Universidad de Alicante, 03690 Alicante, Spain

pablo.sanjose@csic.es

Abstract: A clear demonstration of topological superconductivity (TS) and Majorana zero modes remains one of the major pending goal in the field of topological materials. One common strategy to generate TS is through the coupling of an s-wave superconductor to a helical half-metallic system. Numerous proposals for the latter have been put forward in the literature, most of them based on semiconductors or topological insulators with strong spin-orbit coupling. Here we demonstrate an alternative approach for the creation of TS in graphene/superconductor junctions without the need of spin-orbit coupling. Our prediction stems from the helicity of graphene's zero Landau level edge states in the presence of interactions, and on the possibility, experimentally demonstrated, to tune their magnetic properties with in-plane magnetic fields. We show how canted antiferromagnetic ordering in the graphene bulk close to neutrality induces TS along the junction, and gives rise to isolated, topologically protected Majorana bound states at either end. We also discuss possible strategies to detect their presence in graphene Josephson junctions through Fraunhofer pattern anomalies and Andreev spectroscopy. The latter in particular exhibits strong unambiguous signatures of the presence of the Majorana states in the form of universal zero bias anomalies. Remarkable progress has recently been reported in the fabrication of the proposed type of junctions, which offers a promising outlook for Majorana physics in graphene systems.

Figures



Sketch of the proposed device hosting Majoranas, in yellow. The corresponding dI/dV from the red probe as a function of bias and magnetic flux is shown in the backdrop