Graphene: the good, the bad, and the beauty

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Graphene is probably the most fascinating material ever discovered, but it has some drawbacks: it has no gap, it is not superconducting, and it has a weak spin-orbit coupling. The interesting electronic properties of graphene, such as the presence of charge carriers that behave as if they would have no mass, are rooted on the honeycomb lattice of the carbon atoms. A key question in this regard is: if we engineer a honeycomb lattice out of semiconducting nanocrystals, is it going to behave like graphene or like the semiconducting building blocks?

In the first part of the talk, I will show that these systems, which have been experimentally synthesized last year [1], combine the best of the two materials. Honeycomb lattices of semiconducting nanocrystals exhibit a gap at zero energy, as well as Dirac cones at finite energies. In addition, they display topological properties [2], characteristic of the so-called topological insulators, but at room temperature [3].

In the second part of the talk, I will discuss how to describe the full dynamical electromagnetic interaction in 2D systems like graphene, where the electrons are constrained to move in the 2D plane, whereas the photons move in 3D. By using the so-called pseudo-QED approach, I will show how quantized currents emerge at the edges of this system, while the bulk remains insulating [4].

[1] M. P. Boneschanscher et al, Science **344**, 1377 (2014).
[2] E. Kalesaki et al., Phys. Rev. X **4,** 011010 (2014).
[3] W. Beugeling et al., Nature Commun. **6**, 6316 (2015).
[4] E. Marino et al., Phys. Rev. X **5,** (2015).