Electronic confinement types and geometry dependence in bilayer graphene

Nassima Benchtaber, David Sánchez and Llorenç Serra

IFISC (CSIC-UIB) Palma de Mallorca – Spain.

nassima@ifisc.uib-csic.es

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Abstract

We investigate the electronic confinement in bilayer graphene by topological loops. These loops are created by lateral gates acting via gap inversion on the two graphene sheets. For large-area loops the spectrum is well described by a quantization rule depending only on the loop perimeter. For small sizes, the spectrum depends on the loop shape. We calculated spectrums with and without magnetic field.

Motivation

The aim of this work is to study the electronic confinement in bilayer and the geometry dependence due to the potential applied to the two sheets of the material. We propose two types of confinement mechanism:

- ❖ Trivial confinement: When all the top gates potential in the same sheet have the same sign of potential in opposite to all gates in the bottom. (Fig.1)
- ❖ Topological confinement: When the gate potential changes sign (kink potential) on the same sheet with the corresponding sign reversal on the second sheet. (Fig.2)

Topological confinement in BLG loops
Model used

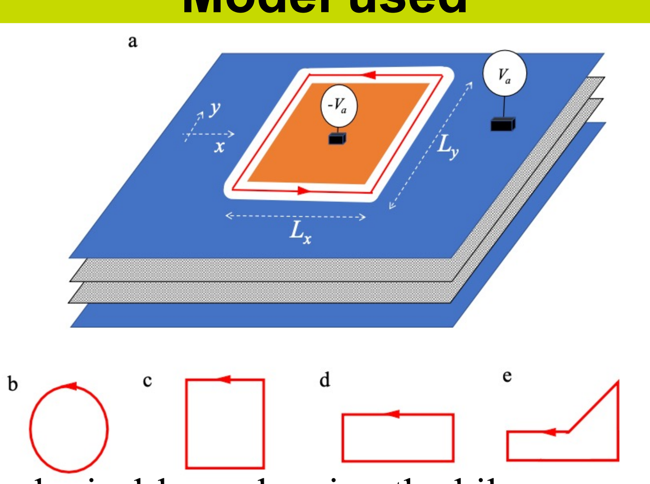

Figure 3: a) Scheme of a topological loop showing the bilayer graphene sheets (gray) and lateral gates with the applied gate potentials ±Va (orange and blue, respectively). Two identical lower gates, hidden behind the lower graphene sheet, have the opposite potentials of the corresponding top gates. The white 1D region between orange and blue gates hosts the topological loop state on the graphene sheets, with counter propagation for the two valleys. A red arrow is indicating the circulation for only one of the two valleys. b)-e) Loop shapes considered in this work, from highest to lowest symmetry: circle, square, rectangle and irregular polygon.

To study the topological states behavior forming a loop in different shapes we have used two models:

1. A quantum perimeter model which is an analytic relation based on Ref.2: with the momentum $p=f_{1,2}$. We obtain the resulting condition that can derive the bound states E for a given loop perimeter, magnetic flux and quantum number .

$$f_{1,2}(E) = \frac{2\pi\hbar}{\wp}\left(\frac{\phi}{\phi_0} + n\right)$$

2. A quantum 2D model, in where we have a low energy Hamiltonian describing the states formed in 2D BLG near Dirac points:

$$H = v_F\left(P_x - \hbar\frac{y}{2l_z^2}\right)\tau_z\sigma_x + v_F\left(p_y + \hbar\frac{x}{2l_z^2}\right)\sigma_y + \frac{t}{2}(\lambda_x\sigma_x + \lambda_y\sigma_y) + V_a(x,y)\lambda_z$$

The two electronic confinement types in the BLG wire

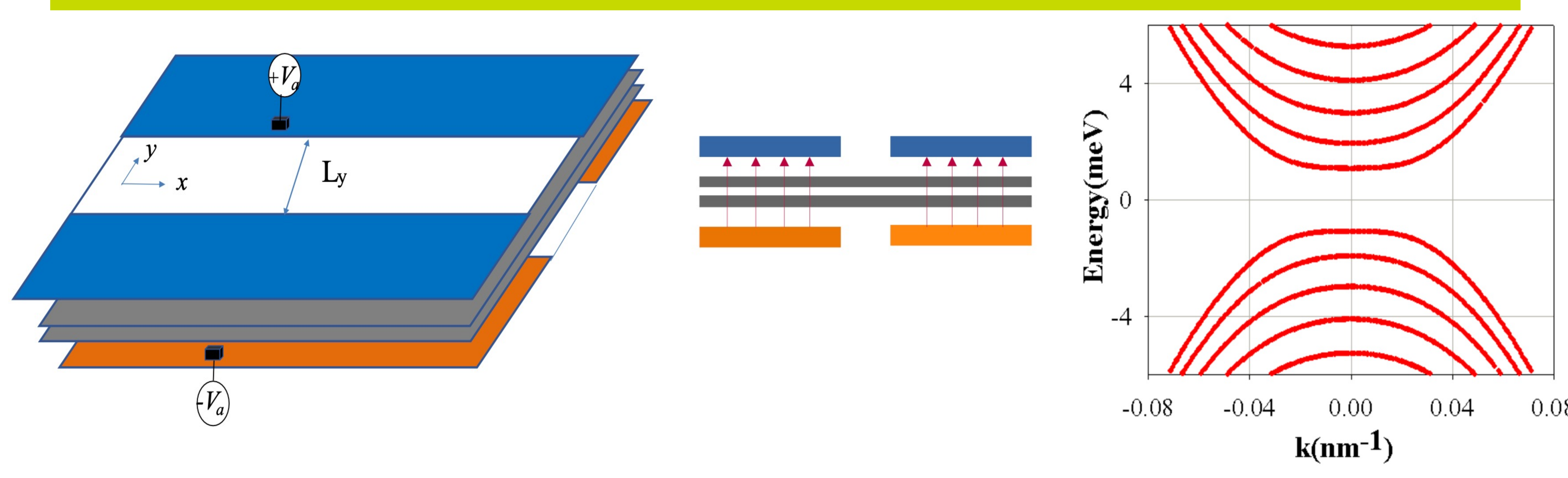

Figure1: Sketch representing gated bilayer graphene with same potential in the same sheet, and the plot of the energy spectrum as a function of the momentum k describe the gap region at zero energy.

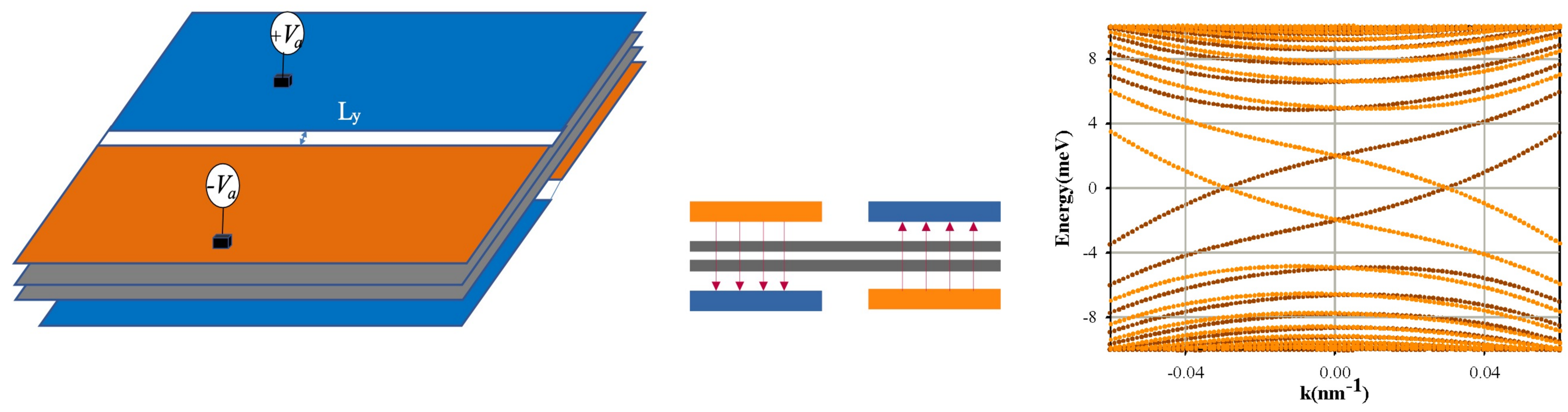

Figure2: Sketch representing the two sheets of graphene under kink potential, and the plot of the energy spectrum as function of momentum in where the kink states appears .

Results

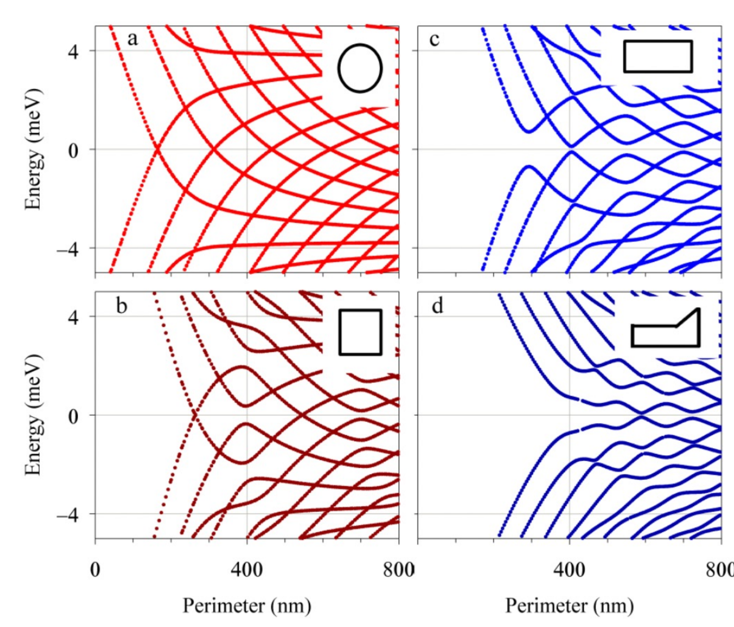

Figure 4: Q2DM energy spectra as a function of perimeter for circle (a), square (b), rectangle with aspect ratio Ly=Lx/2(c) and irregular polygon (d).

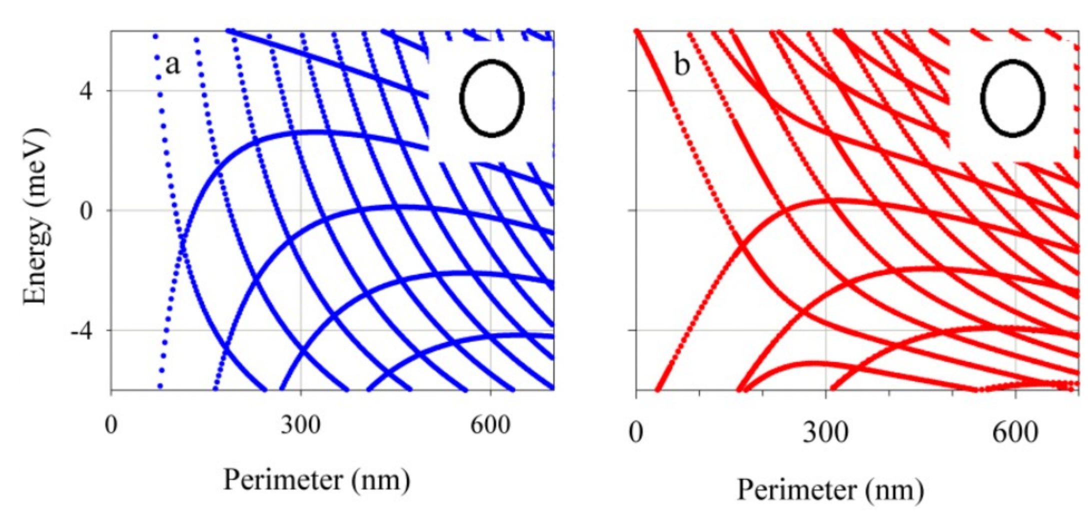

Figure5: QPM (a) and Q2DM (b) energy spectrum for acircle as a function of its perimeter at B=0.5 T. Parameters: wall potential Va= 10 meV and smoothness= 12.5 nm

- ■ A general good agreement between both models is found. For large sizes, the energy spectra are almost insensitive to the loop shape, as expected from QPM.
- ■ For small sizes, we have found that Q2DM reflects shape dependence in the emergence of zero-energy crossings for circles, alternating crossings-anticrossings for squares, and only anti-crossings for other more irregular structure.

References

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