Tunable atomic collapse in mono- and bilayer graphene*

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A single-atom vacancy in graphene can stably host a local charge which can be gradually built up by applying voltage pulses with the tip of a scanning tunnelling microscope. The response of the conduction electrons in graphene to the local charge was monitored with scanning tunnelling and Landau level spectroscopy, and compared to numerical simulations. As the charge is increased, its interaction with the conduction electrons undergoes a transition into a *supercritical* regime where itinerant electrons are trapped in a sequence of quasi-bound states which resemble an artificial atom. The quasi-bound electron states are detected by a strong enhancement of the density of states within a disc centred on the vacancy site which is surrounded by a halo of hole states [1]. We predict that the atomic collapse effect persists in the presence of a magnetic field and that the critical charge remains unchanged. We show that the atomic collapse regime is characterized: (1) by a series of Landau level anticrossings and (2) by the absence of $B^{1/2}$ scaling of the Landau levels with regard to magnetic field strength [2].

We also showed that similar physics can be realized using a circular p–n junction whose size can be continuously tuned from the nanometre to the micrometre scale. The nanometre-scale junction traps the Dirac electrons in quantum-confined states, which are the graphene equivalent of the atomic collapse states predicted to occur at supercritically charged nuclei. As the junction size increases, the transition to the optical regime is signalled by the emergence of whispering-gallery modes, similar to those observed at the perimeter of acoustic or optical resonators [3].

We found that the atomic collapse in bilayer graphene differs fundamentally from its monolayer counterpart.

*Work done in collaboration with D. Moldovan, E. Andrei, M.R. Masir, J. Mao and Y. Jiang

References

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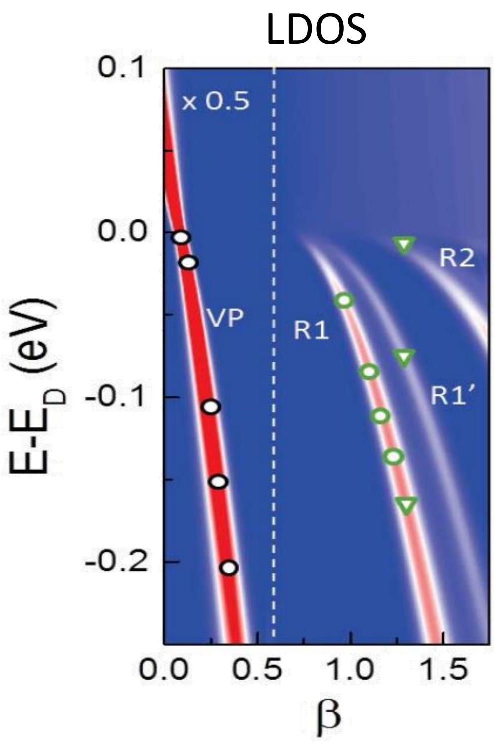

Figure: Energy of the collapse states as function of the effective charge $\beta=Ze^2/\varepsilon\hbar v_F$.