Evidence of Orbital paramagnetism in a graphene/BN moiré

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Measuring the chemical potential dependence of orbital magnetisation in a 2D material reveals fundamental aspects of its band structure, which cannot be detected by usual transport experiments. In particular, the orbital susceptibility has been predicted to exhibit a singularity when the chemical potential reaches the saddle point of an energy band: a paramagnetic logarithmic divergence is expected at the Van Hove singularity of the density of states [1]. Graphene is particularly interesting in this respect, since it can display both diamagnetic and paramagnetic divergent susceptibility, depending on the Fermi energy. The diamagnetic divergence occurs at the Dirac point, and is associated to the emergence of the zeroth Landau level due to the π Berry phase in graphene. The paramagnetic divergence is associated with van Hove singularities (vHs) at the band edges. In pure graphene, vHs are too far in energy to be reached with electrostatic doping and thus these paramagnetic divergences cannot be measured. However, in a moiré of graphene and boron nitride, the superpotential creates mini bands where satellite Dirac peaks appear surrounded by vHs. These features are at lower energies, reachable at moderate gate voltages, in contrast with those in pure graphene. In this experiment, we explored the orbital magnetism of such a moiré system using the same method that allowed the recent detection of the diamagnetic divergence in graphene [2]. The detection of both type of response was possible thanks to the use of giant magnetoresistance sensors (GMRs), insensitive to the out-of-plane field, combined with a gate voltage modulation which enhances sensitivity. We found a set of peaks (both diamagnetic and paramagnetic) that are compatible with the expectations from the band structure and density of states, where a satellite DP is located between two vHs, as shown in figure 1.

[1] Vignale, G. Phys. Rev. Lett., 67-3 (1991), 358-361
[2] Vallejo, et al. arXiv:2012.05357

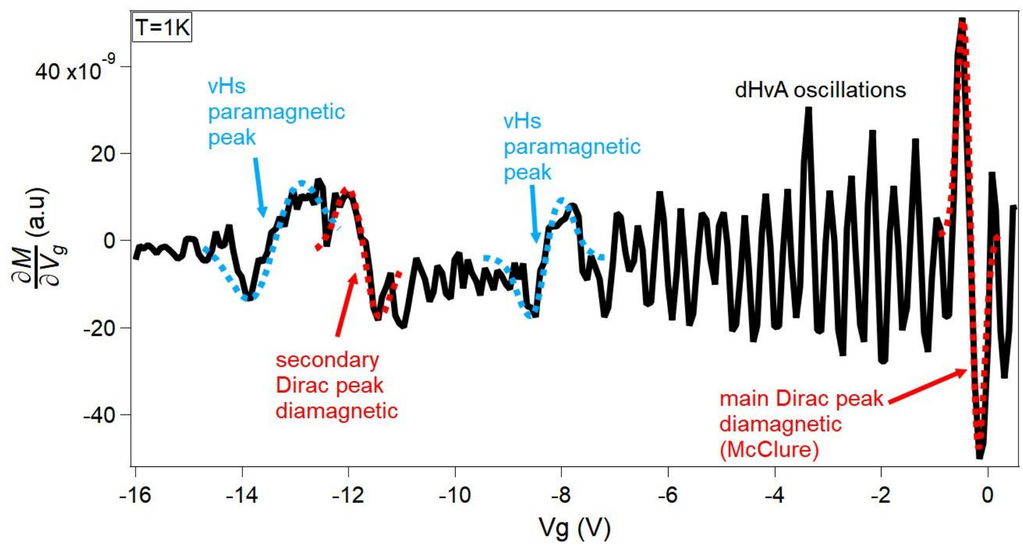

Figure 1: Derivative of the gate-dependent magnetization of graphene/BN moiré for a 1T external field. The shapes of the peaks were drawn for better visualization.