Do we understand the Dirac Point (Spin) Transport Physics in Graphene?

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The ultimate nature of the Dirac point transport physics has been recently experimentally and theoretically debated, with the puzzling increase of the Dirac point resistivity with temperature lowering, in situation of electron-hole puddles screening, and in total contradiction with earlier observations of minimum conductivity. New amazing electronic features also occur at high energy when graphene is weakly interacting with BN layers, and a Moiré pattern develops. The transport physics at those new secondary Dirac points is currently debated, in the context of the first observation of the Hofstadter butterfly. On the other hand, the disorder (or order)-induced valley and spin symmetry breaking has also become an issue of great concern in the Quantum Hall regime, with conflicting or competing mechanisms (defect-induced A/B sublattice degeneracy breaking, electron-electron interaction and quantum Hall ferromagnetism…), introduced to analyze the Landau levels splitting and additional quantized Hall conductance plateaus, sometimes even related to an unconventional dissipative nature of the QHE. Finally spin relaxation mechanism in graphene remains a complete mystery, in which conventional relaxation mechanisms (Elliot-Yaffet and Dyakonov-Perel) seem inappropriate to capture the full picture of spin diffusion in clean graphene.

In this talk, I will first discuss how the Dirac point transport physics evolves from the ballistic to localization regime in presence of defects-induced zero energy modes, and show how Moiré pattern on transport at secondary Dirac point. I will then report on some defect fingerprints in the quantum Hall regime such as energy level splitting, electron-hole asymmetry or the formation of novel types of impurity-pinned magnetic states, at the origin of new Hall conductance plateaus in the QHE phase diagram. Finally, hitherto unknown spin relaxation mechanism unique to graphene will be presented.