Strong magnetoresistance of disordered graphene

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We study theoretically magnetoresistance (MR) of graphene, focusing on the disorder-dominated transport regime with short-range impurities [1]. The key parameter determining magnetotransport properties – a product of the cyclotron frequency and scattering time – depends in graphene not only on magnetic field H but also on electron energy ε. As a result, a strong MR arises already at the semiclassical level within the Drude-Boltzmann approach. For short short-range impurities, the scattering time is inversely proportional to the energy, which translates into the square-root MR ($\propto \sqrt{H}$), particularly pronounced near the Dirac point. Furthermore, for the same reason, "quantum" (separated Landau levels) and "classical" (overlapping Landau levels) regimes may coexist in the same sample at fixed H, giving rise to an additional square-root contribution to the MR. We calculate the conductivity tensor within the self-consistent Born approximation for the case of relatively high temperature, when Shubnikov-de Haas oscillations are suppressed by thermal averaging. We demonstrate that both at very low and at very high magnetic field the longitudinal resistivity scales as a square root of H: $[\rho_{xx}(H)-\rho_{xx}(0)]/\rho_{xx}(0) \approx C\sqrt{H}$ (see Fig. 1), where C is a temperature-dependent factor, different in the low- and strong-field limits. We also predict a non monotonic dependence of the Hall coefficient both on magnetic field and on the electron concentration. Finally, we discuss the case of screened charged impurities and the effects of inelastic collisions and external screening on the MR near the Dirac point. We find that the square-root MR is always established in a generic gated setup at sufficiently low temperature.

References:

[1] P. S. Alekseev, A. P. Dmitriev, I. V. Gornyi, V. Yu. Kachorovskii, arXiv:1210.6081 (submitted to PRB)

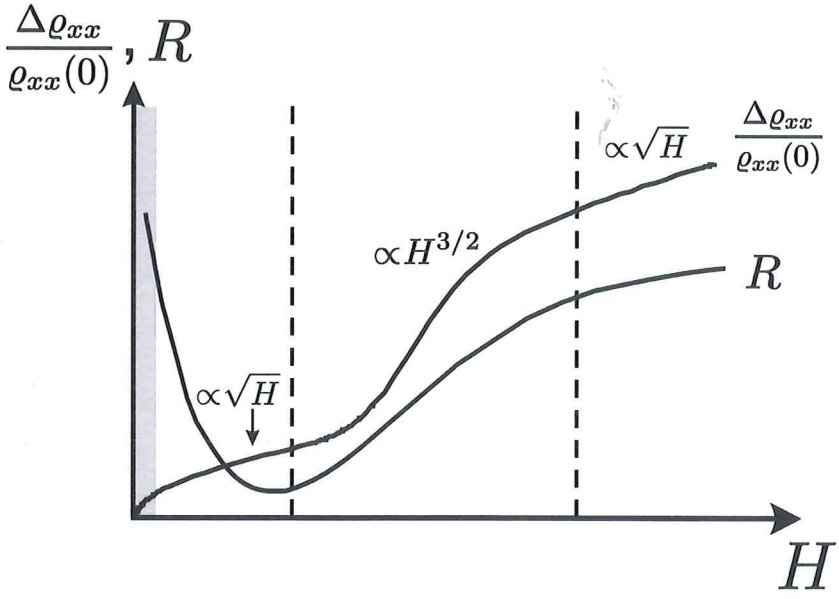

Fig. 1: Schematic plot of the dependence of the longitudinal resistivity and the Hall coefficient on the magnetic field in the vicinity of the Dirac point