ABSENCE OF INTERACTION CORRECTIONS IN GRAPHENE CONDUCTIVITY

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The understanding of the low temperature properties of *interacting* many body systems is one of the most challenging problems in physics; even a weak interaction can radically change the behavior of the non-interacting system and produce a variety of different effects. In view of this, it is particularly interesting that a very small class of observables, among which is the Hall resistivity, appears to be completely *independent* of the interaction and of other microscopic details and that their values only depend upon fundamental constants. Even if there is agreement on the symmetries underlying this *universal* behavior (in the case of Quantum Hall Effect (QHE) it is topological invariance), there is no first-principle derivation of this fact in any interacting many body system. In this talk I will report the first rigorous proof of a universality phenomenon concerning the optical conductivity of half-filled graphene with weak short range interactions, deduced from an interacting lattice Hamiltonian.
Indeed, recent optical measurements in graphene show that at half-filling and small temperatures, if the frequency is in a range between the temperature and the band-width, the conductivity is essentially constant and equal, up to a few percent, to $\sigma_0 = \frac{e^2}{h}\frac{\pi}{2}$, a universal value only depending on the fundamental von Klitzing constant h/e^2 and not on the material parameters, like the Fermi velocity. Such value coincides with the theoretical prediction in a system of massless non-interacting Dirac particles, a widely used effective model of half-filled graphene; remarkably, the inclusion of lattice effects and nonlinear bands does not change such value, as proved by Stauber, Peres and Geim. Of course, interaction effects could produce modifications to this theoretical value, obtained in the free-gas approximation. However, in the case of weak short range interactions and at half-filling, we *rigorously establish* that this is not the case: all the interaction corrections to the zero temperature and zero frequency conductivity cancel out exactly, as a consequence of exact lattice Ward Identities (WI) and of suitable regularity properties of the current-current response function. Besides an obvious interest for the physics of graphene, the universality phenomenon reported here appears to be closely related to the universality in the QHE and to the non renormalization of the anomalies in quantum electrodynamics. Graphene provides a realization of the analogue of such phenomena in a much simpler context, both from an experimental and theoretical point of view.
An important point of our analysis is that, even if irrelevant in the Renormalization Group (RG) sense, the effects of the underlying honeycomb lattice and the non-linear bands are essential for the universality of conductivity in the interacting case; by using the Dirac effective description, which has been successfully used to explain several properties of graphene, one easily misses the *exact cancellations* necessary for universality. In the case of long range interactions, finite frequency corrections to the conductivity were computed, among the

others, by Mishchenko, Herbut, Sheehy, but different values were found, depending on the regularization chosen to cure the spurious ultraviolet divergences introduced by the Dirac approximation. In the case of short range interactions, a momentum regularization of the Dirac effective model produces non vanishing corrections to the universal optical conductivity, but this is believed to be a spurious effect. Our analysis clarifies why *universality cannot emerge in the Dirac approximation.*

The novelty of our approach is the use of constructive RG methods combined with exact lattice Ward Identities. These are believed to play a crucial role also in the understanding of other universal phenomena, like the QHE, which are still not accessible to a first-principle analysis. Our proof shows the crucial role played by the lattice and by the non-linear bands in the emergence of universality and strongly suggests that these will play an important role also in the understanding of the effects of disorder or long range interactions on graphene's conductivity.

Talk based on joint work with V. Mastropietro and M. Porta.