EXACT RENORMALIZATION GROUP FOR GRAPHENE: BEYOND THE DIRAC APPROXIMATION

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The effects of interaction in Graphene are usually analyzed within the Dirac approximation, but it is important to understand also the effects of the lattice and of the non-linear bands; this can be done by the methods of exact Renormalization Group, which do not require linearization and provide in several cases non-perturbative results.
In [1, 2] we have analyzed the Hubbard model on the honeycomb lattice as a model for single layer graphene with screened Coulomb interactions; non-perturbative Renormalization Group techniques rigorously exclude at weak coupling the presence of magnetic or superconducting instabilities or the formation of a mass gap. The Fermi velocity remains close to its non-interacting value and turns out to be isotropic; as a consequence, the Dirac cones are isotropic at low energies.
While the Fermi velocity or the wave function renormalization are modified by the interaction, we prove [3] the *exact vanishing* of the interaction corrections to the zero temperature and zero frequency conductivity of graphene in the presence of weak short range interactions, so solving a theoretical dispute. Such result is the analogue of the Adler-Bardeen theorem on the non-renormalization of the quantum anomalies and show the importance of going beyond the Dirac approximation; even if irrelevant in the Renormalization Group sense, lattice effects and non-linear bands are essential for the universality of a.c. conductivity, similarly as what happens in [4].
Finallly we analyze the effects of the electromagnetic (e.m.) electron-electron interaction in half-filled graphene, investigated in terms of a *lattice gauge theory model* where tight binding electrons hopping on a honeycomb lattice are coupled to a three-dimensional quantum e.m. field. By using exact Renormalization Group methods and lattice Ward Identities, we show that the quasi-particle weight vanishes at the Fermi points and the effective Fermi velocity tends to the speed of light as power laws with non-universal critical exponents. The critical exponents of the response functions are computed, and they indicate a tendency towards excitonic pairing.
Including the interaction with a classical phonon
eld we derive, by a variational argument, an exact non-BCS self-consistence equations for the excitonic gap, admitting a non-trivial solution if its critical exponent exceeds a critical value.

References

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