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A Fermi Liquid with Spin-Orbit Coupling

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Abstract:

A large class of systems of current interest (2D electron gases with spin-orbit coupling, surface states of 3D topological insulators) can be classified as "chiral Fermi liquids", i.e., Fermi liquids with non-trivial correlations between electron momenta and spins. We extend the Fermi-liquid (FL) theory to include spin-orbit (SO) splitting of the energy bands, focusing on the Rashba SO coupling as an example. We construct the phenomenological Landau interaction function for such a system using the symmetry arguments and verify this construction by an explicit perturbative calculation. The Landau function is used to obtain the effective mass, compressibility, and stability conditions of the FL. It is shown that although the charge-sector properties, such as the effective mass and compressibility, are determined solely by well-defined quasiparticles, the spin-sector properties, such as the spin susceptibility, contain a contribution from damped states in between the spin-split Fermi surfaces, and thus cannot be fully described by the FL theory, except for the case of weak SO coupling. We also show that chiral FLs supports a new kind of collective modes—chiral spin waves—and propose experiments in which they can be observed.