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Hydrodynamics in isotropic and anisotropic Dirac-systems

In the hydrodynamic regime it is possible to investigate the universal collision-dominated dynamics of the isolated electron fluid, while the couplings to the lattice and to impurities becomes seconadry. This regime has become recently experimentally accessible such as the observance of the break-down of the Wiedemann-Franz law [1,2], negative local resistance [3,4] and a giant magnetodrag [5] in graphene as well as the dependence of the magnetoresistivity on the length of the sample for $PdCoO_2$ [6,7] and (Al,Ga)As heterostructures[8] show.
Thus far hydrodynamic behavior has been studied in systems with high symmetry of their electronic spectrum, such as Dirac-fluids and Galilei invariant Fermi liquids.
We will study the hydrodynamic behavior in anisotropic Dirac-systesms, i.e. systems where two Dirac cones merge in momentum space [9,10]. These systems have in one direction a parabolic enery dispersion relation while in the perpendicular direction their energy dispersion will be linear as can be seen in Figure 1. This anisotropy leads to fascinating transort properties. In the same material metallic and insulating behavior can be found depending on the direction of the electrical field which is shown in Figure 2. Furthermore we find for the shear viscosity coefficents different temperature functions depending on the flow direction. In fact, the infamous ratio η/s of the viscosity and entropy density diverges and vanishes, depending on the electron-flow direction, violating the lower bound obtained from the duality of strongly coupled field theories and gravity models [11].

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Figures

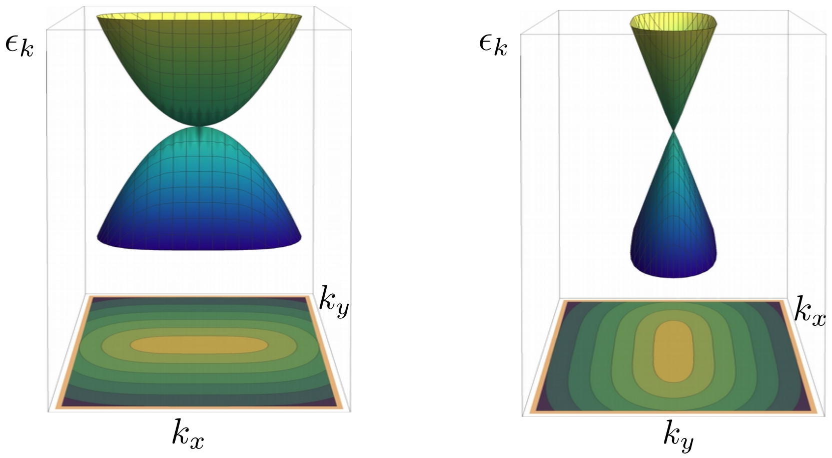

Figure 1: Energy dispersion of anisotropic Dirac-systems. The energy dispersion relation is parabolic in one direction and linear in the perpendicular one.

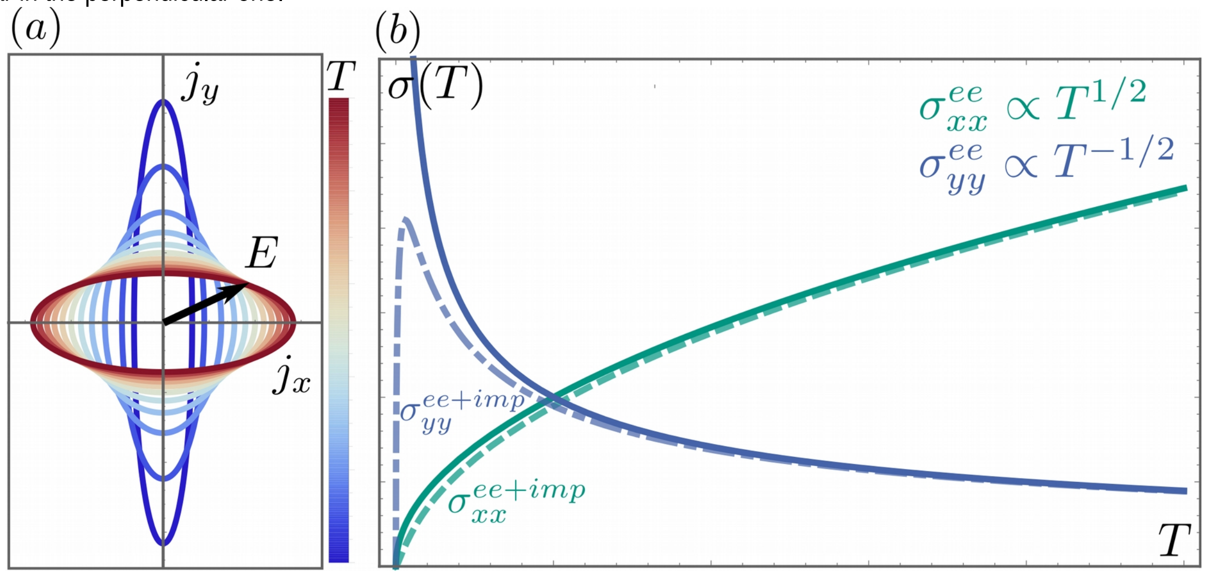

Figure 2: Temperature dependence of the conductivity. The anisotropic Dirac-system shows metallic behavior in the direction with the linear energy spectrum and insulating behavior when the electrical field is aligned along the direction of the parabolic energy dispersion

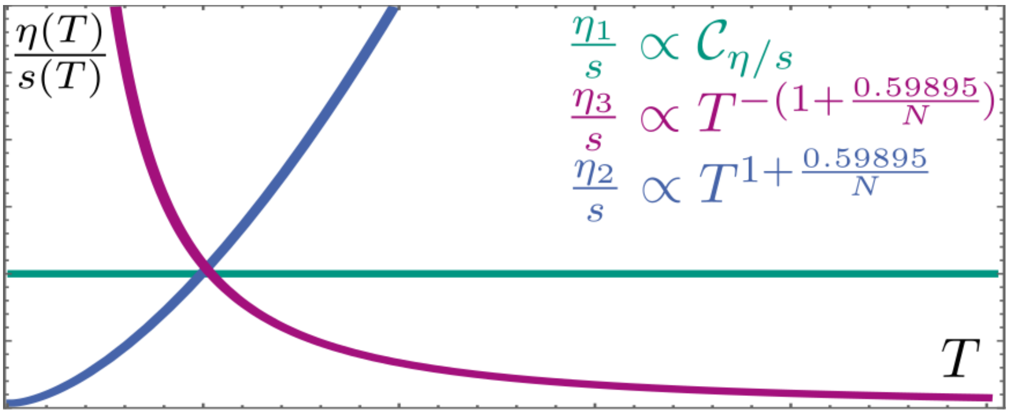

Figure 3: The temperature dependence of the ratio of the different shear viscosity coefficients over the entropy of the system is shown. For small T the ratio vanishes and violates thus the lower bound.