Optical conductivity of a two-dimensional metal near a quantum-critical point: the status of the "extended Drude formula"

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The optical conductivity of a metal near a quantum critical point (QCP) is expected to depend on frequency not only via the scattering time but also via the effective mass, which acquires a singular frequency dependence near a QCP. We check this assertion by computing diagrammatically the optical conductivity, $\sigma(\Omega)$, near both nematic and spin-density wave (SDW) quantum critical points (QCPs) in 2D. If renormalization of current vertices is not taken into account, $\sigma(\Omega)$ is expressed via the quasiparticle residue Z (equal to the ratio of bare and renormalized masses in our approximation) and transport scattering rate as $\sigma(\Omega) \sim Z^2 \gamma_{tr}/\Omega^2$. For a nematic QCP, $\gamma_{tr} \sim \Omega^{4/3}$ and $Z \sim \Omega^{1/3}$. The generalized Drude formula then suggests that $\sigma(\Omega)$ tends to a constant at $\Omega = 0$. We explicitly demonstrate that the actual behavior of $\sigma(\Omega)$ is different due to strong renormalization of the current vertices, which cancels out a factor of Z^2. As a result, $\sigma(\Omega)$ diverges as $1/\Omega^{2/3}$, as earlier works conjectured. In the SDW case, we consider two contributions to the conductivity: from hot spots and from\lukewarm" regions of the Fermi surface. The hot-spot contribution is not affected by vertex renormalization, but it is subleading to the lukewarm one. For the latter, we argue that a factor of Z^2 is again cancelled by vertex corrections. As a result, $\sigma(\Omega)$ at a SDW QCP scales as $1/\Omega$ down to the lowest frequencies.

References

[1] A.V. Chubukov and D.L. Maslov, *Phys. Rev. B* 96, 205136 (2017)