Lorentz ratio in compensated metals: application to WP_2

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Introduction: According to the Wiedemann-Franz law, the Lorentz ratio, $L \equiv \frac{\kappa}{\sigma T}$ (where κ and σ are the thermal and electrical conductivities, respectively) is given by the Sommerfeld constant, $L_0 = \frac{\pi^2}{3}(k_B/e)^2$. Recent measurements [1,2] on a type-II Weyl semimetal WP_2 have shown that Lorentz ratio is up to a factor of 5 smaller than the Sommerfeld constant (Fig. 1, left panel). This naturally calls for revisiting the transport theory of compensated metals.

Results and Discussion: We adopted a simple model of a compensated metal consisting of two parabolic bands Coulomb interaction between the carriers. Due to compensation, electron-hole interaction alone suffices to render the conductivity finite (Baber mechanism). We calculated the Lorentz ratio in this model by solving exactly the system of coupled Boltzmann equations. Our results show that a downward violation of the Wiedemann-Franz law is possible only if electron-hole scattering is the forward-scattering type. In this case, $\frac{L}{L_0} = \langle \vartheta^2 \rangle / 2$, where ϑ is the scattering angle. Forward-scattering limit is realized due to poor screening in Weyl semimetals of the WX_2 family with large (>30) values of the lattice dielectric constant.

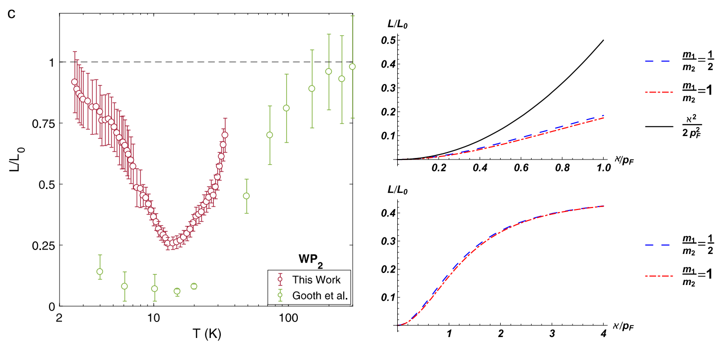

Figure 1. Left: Measured Lorentz ratio in bulk WP_2 vs temperature. Right: calculated Lorentz ratio for a model of a two-band compensated metal with Coulomb interaction between carriers; κ is the inverse screening length.

Conclusions: Our results confirm that there is no limit on how small the Lorentz ratio can be, given that electron-hole scattering is of the forward-scattering type. A strong suppression of the Lorentz ratio is not necessarily indicative of the hydrodynamic regime of electron transport but can also be observed in a bulk sample [2,3].

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References

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