凝縮系物理学ゼミナール

Condensed Matter Seminar

Date: 13:30-15:00, Wednesday, 2 November 2022

Title: Strong Violation of the Wiedemann-Franz law in magnon fluids
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Abstract:

Quantum transport has attracted a profound growth of interest owing to its fundamental importance and many applications in condensed matter physics. Recent significant developments in experimental techniques have further boosted the study of quantum transport. Notably in ultraclean systems, strong interactions between quasi-particles drastically affect the transport properties, resulting in an emergent hydrodynamic behavior. The most-studied example is the hydrodynamic charge transport in metals, which gives rise to an active research field called electron hydrodynamics [1]. This concept has revealed various unconventional transport phenomena such as the negative nonlocal resistance [2] and violation of the Wiedemann-Franz (WF) law [3].

Recent experiments on ultrapure ferromagnetic insulators have opened up new pathways for magnon hydrodynamics [4]. Hydrodynamic magnon transport implies exhibiting extraordinary features [5] as well as electron hydrodynamics and has a potential for innovative functionalities beyond the conventional non-interacting magnon picture. However, the direct observation of magnon fluids remains an open issue due to the lack of probes to access the time and length scales characteristics of this regime.

In this work, we derive a set of coupled hydrodynamic equations for a magnon fluid and study the spin and thermal conductivities by focusing on the most dominant time scales [6]. As a hallmark of the hydrodynamic regime, we reveal that the ratio between the two conductivities shows a large deviation from the so-called magnonic WF law [7]: a magnon-analog of the celebrated WF law [8]. We also identify an origin of the drastic breakdown of the magnonic WF law as the difference in relaxation processes between spin and heat currents, which is unique to the hydrodynamic regime. Therefore, our results will become key evidence for an emergent hydrodynamic magnon behavior and lead to the direct observation of magnon fluids.

Reference:

[1] J. Crossno et al., Science 351, 1058 (2016).
[2] D. Bandurin et al., Science 351, 1055 (2016).
[3] J. Gooth et al., Nat. Comm. 9, 4093 (2018).

[4] C. Du et al., Science 357, 195 (2017).
[5] C. Ulloa et al., PRL 123, 117203 (2019).
[6] R. Sano & M. Matsuo, arXiv:2208.14458
[7] K. Nakata et al., PRB 92, 134425 (2015).
[8] G. Wiedemann & R. Franz, Ann. Phys. Chem. 89, 497 (1853)