凝縮系物理学ゼミナール
Condensed Matter Theory Seminar

Date: 13:30-15:00, Wednesday, 22, January 2025

Title: Theoretical study on loop current phase and non-reciprocal transport in Kagome Superconductors

Speaker: Dr. Rina Tazai (YITP)

Language: Japanese

Abstract:

In the Kagome superconductor AV3Sb5, time-reversal symmetry breaking has been observed through various experiments such as μSR, STM, and NMR [1]. One of the possible origins for this is the loop current (LC) order (often referred to as iCDW). The order parameter of LC is described as a symmetry-breaking part of the self-energy of the electronic system. In Hermitian systems, it can be simply expressed as the pure imaginary hopping term. The orbital magnetization induced by such LC is expected to be very small (estimated to be around 10^-3-10^-2 μB at the center of sites in the Kagome lattice), making direct experimental observation difficult.

One key experiment for indicating the LC is the nonlinear response [2] in 2022. They measured the 2ω component of the voltage V^2ω, which is proportional to the square of the electric field E^ω, it was found that $\rho_{zz} \propto (1 + \gamma \cdot B_x \cdot J_z)$. Furthermore, it was discovered that the coefficient γ, which was traditionally considered a material-dependent constant, jumps depending on the B_z. Such a jump behavior cannot be accounted for in the conventional polar-type nonlinear response theory, such as $R \propto [1 + \gamma(\boldsymbol{P} \times \boldsymbol{B}) \cdot \boldsymbol{I}]$ (refer to [3]). In this study [5], we start from the Boltzmann equation under the LC order and go beyond the conventional approximation by considering higher-order terms in relaxation-time τ [4], developing a theoretical formula for this jump-type nonlinear response. As a result, we found that the jump term, which could not be explained by the conventional τ^2 term, can be explained by the τ^3 term. Furthermore, by applying the obtained formula to a two-orbital 12-site Kagome model and performing numerical analysis, we found that the dominant component of the nonlinear conductivity is large at band crossing points, and even larger at points where the orbital character changes sharply. This behavior can be understood using the concept of quantum geometry, where the conductivity resonates with the LC gap size. (The present nonlinear conductivity is considers as "quasi"-quantum geometry, as its dimension differs by the [energy]^1.)

References:

[1] C. Mielke et al., Nature **602**, 245 (2022).

[2] C. Guo et al., Nature **611**, 461 (2022).

[3] Y. Tokura, et al., Nat. Commun.**9**, 3740 (2018).

[4] X. Liu et al., arXiv: 2303.10164 (2023).

[5] R. Tazai et al., arXiv:2408.04233