



## Seminar

September 2022

2022.9.21 (Wed)

Probability Seminar(11:00--12:30 【Venue: Online】 )

**Speaker :** Dimi Culcer (The Univ. of New South Wales, Australia)

**Title :** Semiclassical equations of motion for disordered conductors: extrinsic velocity and corrected collision integral

**Abstract :**

The semiclassical equations of motion are widely used to describe carrier transport in conducting materials. Nevertheless, the substantial challenge of incorporating disorder systematically into the semiclassical model persists, leading to quantitative inaccuracies and occasionally erroneous predictions for the expectation values of physical observables. In the present work we provide a general prescription for reformulating the semiclassical equations of motion for carriers in disordered conductors by taking the quantum mechanical density matrix as the starting point. We focus on external electric fields, without magnetic fields, and spin-independent disorder. The density matrix approach allows averaging over impurity configurations, and the trace of the velocity operator with the disorder-averaged density matrix can be reinterpreted as the semiclassical velocity weighted by the Boltzmann distribution function. Through this rationale the well-known intrinsic group and anomalous velocities are trivially recovered, while we demonstrate the existence of an extrinsic interband velocity, namely a disorder correction to the semiclassical velocity of Bloch electrons, mediated by the interband matrix elements of the Berry connection. A similar correction is present in the non-equilibrium expectation value of the spin operator, contributing to spin-orbit torques. To obtain agreement with diagrammatic approaches the scattering term in the Boltzmann equation is corrected to first order in the electric field, and the Boltzmann equation is solved up to sub-leading order in the disorder potential. Our prescription ensures all vertex corrections present in diagrammatic treatments are taken into account, and to illustrate this we discuss model cases in topological insulators, including the anomalous Hall effect as well as spin-orbit torques.

\*This seminar is co-sponsored by Tohoku University AIMR. Please note that the day and time of this seminar are different from the usual ones.

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