

Emergent electromagnetism in solids - Spin-orbit interaction as a gauge field

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Electromagnetic field and the electronic interactions induced by it is the most fundamental to condensed matter physics. In addition to this, it often happens that the electronic system itself produces the effective internal electromagnetic field due to the various interactions as an emergent phenomenon. This is related to the quantum Berry phase associated with the constraint imposed on the Hilbert space in the low energy sector. Many nontrivial phenomena such as the anomalous Hall effect, spin Hall effect, and ferroelectric polarization originate from this Berry phase.

In this talk, I will focus on the relativistic spin-orbit interaction. In the non-relativistic approximation, the electron-positron pair creations can be neglected leading to the projection of the Hilbert space to the positive energy solutions to the Dirac equation. Therefore, the spin-orbit interaction can be regarded as a non-Abelian Berry gauge field. As two representative examples of the applications of this idea, Skyrmion dynamics in magnets and the spin current conservation law will be discussed.