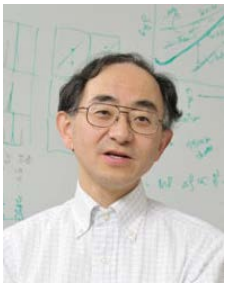
【Grant-in-Aid for Scientific Research(S)】

Science and Engineering (Mathematical and physical sciences)



# Title of Project： Emergent Electromagnetism in Magnets

Naoto Nagaosa
( The University of Tokyo, Graduate School of Engineering,
Professor )

Research Area：Physical and Mathematical Science
Keyword：Magnetism

## 【Purpose and Background of the Research】

Condensed matter physics is now in the middle of the new developments originating from the quantum Hall effect and high temperature superconductivity, the former of which established the vital role of electron correlation, while the latter introduced the concept of topology. These two main streams now merge into a new direction based on the concept of "emergence". The present study aims at the construction of a new electromagnetism, i.e., emergent electromagnetism, for the electrons in solids especially in magnets. The theoretical framework describing the nontrivial spin structures in real-space such as Skyrmion and monopole, and the Berry phase in momentum space will be developed, and various new phenomena will be predicted theoretically and investigated experimentally including the magnetism, electric polarization, quantum transport, optical processes, and thermal transport. The topological magnets are searched, and the dynamical phenomena will be studied.

## 【Research Methods】

Theoretical team will design using the first-principles band structure calculation and quantum field theory, and the two experimental groups will perform the material design, material synthesis, measurements of physical properties, and explore the spin structures and spin dynamics mainly in terms of the neutron scattering experiment to establish the emergent electromagnetism in magnets. More concretely, there are 3 main themes as follows. **(i) Topological magnets in real-space:** the Skyrmion structure realized in the thin film of helical magnets is an ideal laboratory for the emergent electromagnetism (Fig.1). Spin structure analysis by the small angle neutron scattering experiment, Hall effects, spin electromotive force, current-driven phase transition, and noise will be studied both theoretically and experimentally, and the "Skyrmionics" will be established. **(ii)Berry phase in momentum space:** By doing the magnetic impurities into topological insulators, we will explore the possibility of quantized anomalous Hall effect. In the interface/superlattice of oxides, we theoretically design the topological insulator/magnets, perform the experiments on the related system by MBE and EDLT.

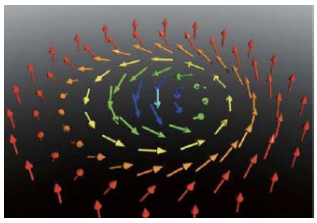


Figure 1: Skyrmion

**(iii)Dynamics of emergent electromagnetism:** Time-dependent phenomena related to the magnons will be studied. Optical ME effect due to electro-magnon, directional dichroism, magneto-optical effects, inelastic neutron scattering will be investigated.

## 【Expected Research Achievements and Scientific Significance】

The establishment of "emergent electromagnetism" in solids will contribute tremendously to the basic science as well as to the ultra-low energy consumption electronics by the dissipationless currents via the following concrete new functions. (1) Huge emergent magnetic field by weak electric/magnetic field. (2) Quantized Hall effect and dissipationless currents at room temperature and weak magnetic field. (3) Non-reciprocal responses at Tela-Hertz region.

## 【Publications Relevant to the Project】

・Emergent phenomena at oxide interfaces
H.Y.Hwang et al. Nature Materials 11, 103 (2012).
・Emergent electromagnetism in solids
Naoto Nagaosa and Yoshinori Tokura, PHYSICA SCRIPTA T146, 014020 (2012)

【Term of Project】FY2012-2016

【Budget Allocation】167,700 Thousand Yen

## 【Homepage Address and Other Contact Information】

http://park.itc.u-tokyo.ac.jp/nagaosa-lab/