１．Research plan

[Subject]：**Spin textures induced by frustration**

[Aim]：**Frustrated magnets** with competing interactions often exhibit novel behaviors in their magnetic and transport properties due to characteristic fluctuations which emerges from the effects of **frustration**. In particular, **topologically stable** nono-size **spin textures** induced by frustration are quite interesting both from fundamental and application standpoints. In the present research project, we target at topologically stable spin textures retaining the active **chirality** degrees of freedom of "right" or "left", including **skyrmions** and **Z_2 vortices**. In contrast to the anti-symmetric spin textures stabilized by the Dzyaloshinskii-Moriya interaction, they possess rich internal degrees of freedom associated with the degenerate chirality degrees of freedom and are expected to exhibit novel phase structures, dynamics, transports and **rich electromagnetic responses** due to the active chirality. Expecting the future application to **spintronics**, much attention is now paid especially to skyrmions Under such circumstances, we wish to conduct theoretical studies on the stabilization conditions of frustration-induced symmetric skyrmions and Z_2 vortices, and their novel thermodynamic, transport and electromagnetic properties. In the next stage, we wish to interact with the experimental group, seeking for the further development of the phenomena in real materials.

[Method]：The theoretical part of the project employs mainly numerical computer simulations. For example, we are planning to perform numerical computation of the dynamical spin structure factor based on the spin-dynamics method, aiming at the comparison and the interpretation of the recently obtained quasi-elastic and inelastic neutron-scattering data. Spin-dynamics simulations of the transport properties borne by **symmetric** skyrmions and Z_2 vortices are also planned. We wish to develop close collaboration between theory and experiment at various levels of research, e.g., sample synthesis, neutron and magnetic X-ray scatterings, thermal and magnetic measurements, various transport measurements, and NMR measurements.

[Expected outcome]: Frustration often induces novel thermodynamic states, excitations and magnetic phenomena, not seen in standard magnets. Possible outcomes expected from the present project might be, from the fundamental research side, to find in frustrated magnets novel thermodynamic and magnetic states, and new types of transports. From the application side, possible rich electromagnetic response due to the active chiral degrees of freedom might provide useful elements to the future application to spintronics.

2. Research results in the past

My research field is theoretical condensed-matter physics and statistical physics, especially, theoretical studies on magnetism and phase transition.

Major subject of my research has been to explore the effects of non-trivial physical elements such as "**frustration** (competition)", "**randomness** (disorder)" and "**strong quantum fluctuations**" on the material properties, especially, the novel ordered states and thermodynamic phases, novel excitations and transport properties. From the early years of mid 80's, I performed a series of pioneering theoretical studies on the **triangular-lattice magnets**, now widely regarded as a typical system of **frustrated magnets**; e.g., 1) finding of novel magnetic orderings in two-dimensional (2D) triangular-lattice Heisenberg antiferromagnets, especially, identification of a novel topological vortex, a **Z_2 vortex**, and a novel **topological transition** associated with **the condensation of the Z_2 vortices**; 2) finding of a **new `chiral' universality class** at the magnetic phase transition of the 3D stacked-triangular-lattice Heisenberg antiferromagnets, and the prediction of the associated critical properties. The predicted critical exponents were observed by subsequent experiments. Furthermore, 3) the proposal of a ``**chirality scenario**" for the ordering of the **spin-glass** magnets regarded as a typical `complex' magnets characterized by frustration and randomness, where the **chirality** plays a vital role as a `hidden' order parameter instead of the spin itself. The scenario has got a rather direct experimental support from the Hall measurements on metallic spin glasses.

Subsequently, research on frustrated systems has seen further developments. In recent **magnetism and spintronics**, **skyrmions** has got a lot of attention as topologically stable spin textures. Skyrmions so far studied were mainly antisymmetric ones realized in the material without the inversion center stabilized by the Dzaloshinskii-Moriya interaction. In contrast, we proposed that a different type of symmetric skyrmions could be stabilized by frustration in the material with the inversion center, and they kept the **chiral degeneracy**, giving rise to the **anti-skyrmions** degenerate with the skyrmions. The other topic attracting a lot of recent attention in the field of magnetism is the "**quantum spin liquid** (QSL)" exhibiting no magnetic order down to very low temperatures. We found by means of numerical computations on certain model systems that the randomness (or inhomogeneity) induced the gapless QSL, the **random-singlet state**, arguing that many of QSL candidate magnets recently reported experimentally might be such randomness-induced ones.

On the basis of statistical physical approach, several works were made in the fields entirely different from the frustrated magnets. For example, 6) the study of **tiling**

problem and its application to **quasi-crystals**, which was made prior to the finding of the quasi-crystal by Shechtman, Nobel Prize of chemistry in 2011. I studied the statistical-mechanical properties of the random tiling of triangles and squares, which actually turned out to be the quasi-crystal of the 12-fold symmetry, establishing the first-order transition to the crystalline state and estimating the entropy of the state. I have also engaged earth-science subject, i.e., 7) statistical physical study of **earthquakes** based on a simple statistical physical model. I succeeded in reproducing a variety of seismic slips such as "**mainshocks**", "**precursory slips**", "**afterslips**" and "**slow-slip events**" within a simple model containing only a few basic parameters, which enables us to get some physical insights in constructing a unified physical picture of earthquakes.

I also studied various other subjects, such as, 8) **quantum melting,** 9) the **vortex order in high-*Tc* superconductors in magnetic fields**, 10) the novel **chiral-glass order in ceramic cuprate superconductors**, and 11) the **superfluidity transition of helium-three film**.

List of scientific papers

Main papers and books

【Scientific papers（refereed)】

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H. Kawamura, Prog. Theor. Phys. **70**, 352-365 (1983).

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20. "Chiral ordering in Heisenberg spin glasses in two and three dimensions"

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Other 76 papers, 162 papers in total

【Books】

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