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Research Results

I have studied supersymmetric gauge theories. Supersymmetry (SUSY) is au invariance under the exchange of particles with different statistical properties, bosons and fermions. SUSY has been applied to various studies as a candidate for physics beyond the Standard Model. For example, in the anti-de Sitter/conformal field theory (AdS/CFT) correspondence, which suggests a deep relationship between gauge theories and gravity theories, a gravity theory is described by a $\mathcal{N}=4$ supersymmetric Yang-Mills theory. Therefore, solving SUSY theories could enable us to make significant progress in areas such as quantum gravity theory can be expected. In order to elucidate the supersymmetric theory, I have been working on the following research.

1. Supersymmetric gradient flow in supersymmetric theory

Lattice gauge theory and gradient flow method are powerful approaches for solving non-perturbative dynamics. Lattice theory involves defining gauge theories on a discretized lattice spacetime and is applied to numerical simulations. However, since both a physical quantity, the energy-momentum tensor, and SUSY are closely related to translational symmetry, it is difficult to formulate them directly on a lattice spacetime, which explicitly violates translational symmetry.

The gradient flow defines a flow equation through the gradient of the action and discusses a smeared gauge field. In the case of Yang-Mills theory, any correlation function generated by the gradient flow automatically becomes finite after renormalizing the original theory. The renormalizability of flowed fields has been used to formulate physical quantities in lattice quantum chromodynamics (lattice QCD) simulations. Additionally, a new methodology with gradient flow is pointed out for constructing supersymmetric theory as a continuous limit from the lattice, and the construction of supersymmetric flow equations has also been proposed.

In collaboration with Kadoh, Maru, and Ukita, we have studied supersymmetric gradient flow in four-dimensional supersymmetric QCD. We investigated the divergence structure of two-point correlation functions at the one-loop level [1]*. Our results show that the divergence cancels out for vector multiplet, while common divergences remain for chiral multiplet with respect to the wave function renormalization. To prove the results of [1] for all orders of perturbation, we constructed a (4+1)-dimensional action equivalent to the four-dimensional flow theory.

2. The MSSM extended to mixed Majonara-Dirac mass

The supersymmetric Standard Model predicts the existence of supersymmetric particles with different statistics for each elementary particle. For example, the minimal supersymmetric Standard Model (MSSM), which incorporates minimal SUSY, contains fermions in adjoint representation with Majorana masses. However, the existence of SUSY particles has not been experimentally confirmed, and supersymmetry must be spontaneously broken in our nature. Since the mechanism of supersymmetry breaking determines the mass of SUSY particles, it is essential to elucidate SUSY breaking in terms of searching for the existence of supersymmetric particles.

In collaboration with Itoyama and Maru, we have studied extending the masses of adjoint fermions in the MSSM to the mixed Majorana-Dirac masses, focusing on spontaneously SUSY breaking of $\mathcal{N}=2$ to $\mathcal{N}=1$. Because of the partial SUSY breaking, the existence of massless fermion is guaranteed for $\mathcal{N}=1$ supersymmetry theories from the Nambu-Goldstone theorem. We have investigated mass matrices and interactions for general $\mathcal{N}=1$ SUSY theory, and partially confirmed the existence of massless fermions. We are now analyzing the mass matrix and interactions more precisely, confirming the existence of massless fermions and discussing their physical consequences.

*[ ] is the paper number in the attached list.