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Summary of my research

As stated in the research plan, I am interested in theoretical particle physics and especially on nonperturbative study of superstring theory and matrix models and I have engaged myself in research on the nonperturbative effects of superstring theory and field theory. I will describe the details of my research below.

Symmetry breakdown in the IIB matrix model Spontaneous symmetry breakdown of the IIB matrix model that is considered to be a candidate of the constructive definition of superstring theory was studied. The IIB matrix modes possesses the rotational symmetry corresponding to the flat ten-dimensional space-time and the breakdown of this symmetry was analyzed. By application of an "improved mean field approximation," we have got the result which suggests that this ten-dimensional rotational symmetry would break down spontaneously and implies that a four-dimensional space-time, maybe corresponding to our universe, can be realized as the most stable vacuum.

Boundary conditions in quantum gravity in a lower dimension By using dynamical triangulation, the relation between the boundary condition of two-dimensional quantum gravity and the geometrical structure on that two-dimensional surface. We have got the result that the geodesic distance on the surface is able to be divergent exponentially with respect to the boundary condition and we have understood geometrically the emergence of a non-compact surface suggested by conformal field theory.

Improved mean field approximation in quantum field theories We tried to apply an "improved mean field approximation" that had been successful for the IIB matrix model to a nonlinear sigma model and nonabelian gauge theory in order to analyze them nonperturbatively. We observed the emergence of the nonperturbative mass term for the fields and confirmed that in the sigma model the result agreed with the result of large-N limit.

Membrane theory in the background field String theory has been considered to have a profound relation with membrane theory whose elementary constituent is a two-dimensional "membrane." We analyzed the dynamics of membranes with boundaries with a constant three-form field as a background and showed that the dynamics of the boundaries obeys a noncommutative algebra.

Classification of nonlocal operators in conformal field theories We pointed out that in conformal field theories nonlocal operators can be classified by representations of the subgroup of the conformal group preserved by the operator, and gave concrete examples for some simple cases. In the subsequent paper, this was applied to Wilson loop operators of circular shape in $\mathcal{N} = 4$ super-Yang-Mills and the renormalization of this Wilson loop was considered. This result was also studied within the frame work of AdS/CFT correspondence. We observed that in the gauge theory side the structure of an open spin-chain appears naturally and the anomalous dimensions of the operators can be calculated by Bethe ansatz. This anomalous dimension can also be calculated in the string theory side and we confirmed that they agreed exactly at the leading order.