Research History

I have been studying various subjects mainly in quantum field theory and string theory.

(1) Mathematical aspects of string theory, M-theory and quantum field theory [4,6,9,10,11,22]*

I studied the string theory by using several mathematical methods, and provided physics with geometric understandings.

- Employing gerbes in mathematics, I extended the phase called discrete torsion in string theory to the one in M-theory, and clarified its non-trivial structure.
- By the use of the ADE multi-matrix model, I clarified the deformation of ADE singularities in the target space of topological string, and approximately reproduced the effective superpotentials in $\mathcal{N} = 1$ supersymmetric quiver gauge theories [6].
- In a (gauged) linear sigma model on a supermanifold, we studied the Calabi-Yau condition for the supermaifold, conformal symmetry, anomalies and so on [9,11].
- So far it has been believed that a two-point string amplitude vanishes due to an infinite volume of residual gauge symmetry. However, employing the operator formalism of string theory, we have shown that the two-point amplitude has a non-zero value [22].

(2) AdS/CFT correspondence (gauge/gravity correspondence) [1,5,12,13,14,15,16,17]

Since the AdS/CFT correspondence was suggested in 1997, it has been applied to various correspondences between gauge theories in strong coupling and gravity theory (string theory) in weak coupling. Nowadays it has been a useful tool for understanding the theories in strong coupling.

- It is known that a kind of configurations of D5-branes correspond to baryons in the dual gauge theory via the AdS/CFT correspondence. I studied such D5-branes in several backgrounds [1,5].
- In holographic QCD (HQCD), which is a model for realizing QCD from gravity by the AdS/CFT correspondence, we have shown the mechanism which yields a current quark mass by tachyon condensation [12,13,14].
- In terms of the HQCD, we studied the breaking/restoration of chiral symmetry in the medium of baryons [16,17].

(3) Quantum entanglement [15,18,19,20,21]

Quantum entanglement is an interesting phenomenon in quantum theories. Recently the research on it has been attracting attention in various research fields; particle theory, condensed matter theory, information theory and so on.

- Considering the causal structure on the open string world-sheet describing the gluon scattering, we have shown there exists a wormhole on this world-sheet. This supports the ER=EPR conjecture [15,18].
- We studied the entanglement of the two-particle final state in an elastic scattering within an S-matrix theory, and we have found the formula which describes the entanglement entropy of such two particles in terms of physical observables at high energy [19,20]. Then, following this formula, we have evaluated the entanglement entropy of two outgoing protons by the use of the experimental data of proton-proton scattering in LHC *etc.* [21]. Furthermore we are trying to extend the understanding of entanglement to inelastic scatterings.

(4) Physics in extra dimensions [2,3,7,8]

- We calculated the contribution of tachyonic Kaluza-Klein modes, which appeared in the compactification of time-like extra dimensions, to the gravitational self-energy of a spherical body. From this result we suggested the relation between the radius and the stability of the spherical body [2,3]. We also suggested the shape of space-like extra dimensions by associating the cosmological constant with the vacuum energy (Casimir energy) yielded by the compactification of the extra dimensions [7,8].

*See "List of publications".