

Research History

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

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

- It is known that a D5-brane in type IIB superstring theory on $AdS_5 \times S^5$ corresponds to a baryon in the gauge theory by the AdS/CFT correspondence. I studied the Dirac-Born-Infeld (DBI) action of a D5-brane at the Penrose limit of the anti-de Sitter space, as a result, I clarified the shape of the baryonic D5-brane at this limit [5]. By analyzing the DBI action of a D5-brane also in type 0 string theory, I have shown the D5-brane corresponds to a baryon in a non-supersymmetric gauge theory [1].
- We considered the open string tachyon between a D8-brane and an anti-D8-brane in Sakai-Sugimoto (SS) model, which is one of the models of holographic QCD, and succeeded in introducing a current quark mass to this model through tachyon condensation [12]. Applying this mechanism, I suggested a new model of HQCD which consists of crossing D4-branes [14]. We generalized the SS model and calculated many properties of baryons from the DBI action of D8-brane. We compared them with experimental data [13].
- Employing the generalized SS model, we studied the breaking/restoration of chiral symmetry in the medium of baryons. Our result agrees with the expectation from the ordinary QCD in low baryon density [16]. Furthermore, we proposed a new model of HQCD whose background was given by D0-D4-branes, and reproduced the behavior of chiral condensate which is expected by the ordinary QCD in high baryon density [17].
- The AdS/CFT correspondence allows us to compute a scattering amplitude from the area of a corresponding minimal surface, which is a classical solution of an open string. From this point of view, we carefully investigated a similarity between the gluon scattering and the quark scattering at the Regge limit [15].

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

- Discrete torsion is originally the phase appearing in a representation of an orbifold group acting on a Chan-Paton factor of an open string. Applying gerbe in mathematics, I extended this phase 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].
- We studied a gauged linear sigma model on a supermanifold, which has anti-commutative coordinates as well as commutative ones. As a result, we showed D-branes embedded into the supermanifold, the structure of classical vacua, the Calabi-Yau condition, superconformal symmetry and so on [9,11].
- In the framework of the continuum string field theory, we calculated the amplitude of a D-instanton in $(p, p+1)$ minimal string, which agrees with the result known from the matrix model [10].

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

- 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 [18]. This implies the geometric understanding of the quantum entanglement between scattering gluons, and supports the ER=EPR conjecture, which relates quantum entanglement with a wormhole.
- We considered the change of the entanglement entropy from the initial state to the final one in a scattering process. We perturbatively calculated it in some concrete models [19]. Furthermore, employing S-matrix and its unitarity, we have found a general formula which describes the entanglement entropy of two outgoing particles in terms of physical observable [20].

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

- We calculated the contribution of tachyonic Kaluza-Klein modes, which appear 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”.