Research achievements

I have studied string theory and related topics. It was around 15 yeas old when I knew about string theory for the first time. Since then, (for nearly 30 years) I have been thinking about this miraculous theory. After I became a researcher, I studied several topics including M2-brane dynamics, AdS/CFT correspondence, tachyon condensation and matrix models.

Recently, I am working on a research aiming at clarifying the properties of M2-branes. M2-branes are important constituents of M-theory, and the understanding of these properties is very important. I am now collaborating with Sanefumi Moriyama (Osaka City University) and studying M2-branes in M-theory on an orbifold. The dynamics of M2-branes can be described in terms of a three-dimensional gauge theory. Interestingly, some of the observables of the gauge theory can be calculated by relating their calculations to those in a one-dimensional Fermi gas system. The simplicity of the Fermi gas system enables us to perform precise analyses. I expect that our recent results will shed light on the properties of M2-branes on some non-trivial backgrounds like the orbifold.

In the above-mentioned study, the main role is played by a three-dimensional gauge theory known as ABJM theory. I have been studying this theory for several years. ABJM theory provides us with an example of AdS/CFT correspondence, and is expected to describe M-theory on a four-dimensional anti-de Sitter space-time. I studied, in collaboration with Soo-Jong Rey (Seoul National University) and Satoshi Yamaguchi (Osaka University), the relation between ABJM theory and the four-dimensional M-theory when I stayed at Seoul National University. Our focus was on the properties of the Wilson loop operator, a non-local operator which plays a fundamental role in gauge theories. In the context of AdS/CFT correspondence, the Wilson loop operator describes a string living in the anti-de Sitter space-time. (Here we compactify M-theory down to ten dimensions and regard it as Type IIA string theory.) To investigate the relation, we analyzed quantum corrections to the Wilson loop operators. Our results has been cited by many papers, regarded as a fundamental achievement on this topic.

Since this collaboration, I have continued researches on ABJM theory and related gauge theories. It was shown that the calculations of the Wilson loop operators can be reduced to the calculations in related matrix models. I have investigated various matrix models related to the gauge theories and, based on the results obtained, discussed general relations between three-dimensional gauge theories and four-dimensional gravity. My resent research revealed that the properties of the matrix models are encoded in a system of ordinary differential equations. A further study on this issue will be fruitful.

AdS/CFT correspondence claims a relation between a quantum field theory without gravity and a quantum theory of gravity whose large part is still unclear. There are huge amount of explicit calculations which support the validity of the correspondence. However, its understanding at the fundamental level is still out of reach. I showed, in collaboration with Hikaru Kawai (Kyoto University), that many claims of AdS/CFT correspondence can be explained by the assumption that there exists an approximate scale invariance in the

perturbative string theory with D-branes. We also gave an argument on the mechanism for the approximate scale invariance to emerge.

I also studied tachyon condensation in string theory. It has been known since the birth of string theory that some of perturbatively-defined string theories contain tachyons in their spectrum. The presence of the tachyons actually indicates that the perturbatively-define vacuum is not appropriate. In such a situation, it is usually expected that a stable vacuum would be realized by the condensation of the tachyon fields. I investigated various string theories with tachyons, and argued the properties of the vacuum which is expected to be realized by a tachyon condensation. One of the papers on this topic was awarded the Particle Physics Medal: Young Scientist Award in Theoretical Physics.