Research summary

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The [number] is the number recorded in the publication list.

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(1) Dynamics of spacetime in higher dimensional supergravity

The unified theories of elementary particles, for example the superstring theory and the supergravity theory, suggest that our universe is higher dimensional. Then it is important to clarify the evolution of four-dimensional universe and an internal space in the cosmology and the elementary particle physics. It is necessary to theoretically explain the reason why we cannot observe the existence of the internal space. We should also solve the problem how to derive the cosmological or inflationary scenario from a higher dimensional theory.

I had interested in some concrete supergravity theories for these problems. I discussed the inflation model and stabilization of an internal space in terms of the shape of moduli potential which is appeared in a four-dimensional effective theory [5, 6]. I considered the quantum effect of various fields which existed in the background. Then, I could obtain the model that had the positive energy of the moduli potential at the minimum value of the potential. We note that the moduli potential behaves as vacuum energy in the four-dimensional theory. This model could realize not only the moduli stabilization but also the four-dimensional de Sitter spacetime [5, 6].

I could obtain the time dependent solution of the Einstein equations in the ten-dimensional type IIB supergravity in the case of the existence of the D3-brane and discussed that the volume of the internal space could not be stabilized [2]. This is the background of the KKLT model which was the topical issue recently.

I also concretely obtained the dynamical solution of four-dimensional Einstein equation after deriving the four-dimensional effective theory [1]. As a result, I noted that there was the solution of four-dimensional Einstein equations which was not that of original higher-dimensional Einstein equations [1].

We could obtain the time dependent solution of Einstein equations for the intersecting brane system in the supergravity theory. In the case of the existence of several kinds of brane, the time dependence appears to field strength whose rank is lowest in the background (e-Print Archive:0712.3615 [hep-th]).

(2) Cosmological constant problem in brane world (BW) model

There is brane world (BW) scenario as a trial model that D3-brane put in the higher dimensional background in order to solve the gauge hierarchy problem in the elementary particle physics. BW provides not only solution of the problem of the gauge hierarchy but also the cosmological model that the graviton can be localized on the D3-brane. I had interested in the fact whether the BW leaded some suggestions for the cosmological constant problem or not. Then I studied the evolution of the four-dimensional cosmological constant in the BW model with the scalar field. I could obtain the four-dimensional Friedmann equation on brane and derive the four-dimensional cosmological constant which was consistent with the observational results without fine-tuning the cosmological parameters. [7]

(3) Quantum field theory in pp - wave background

It is well-known that we can solve the model of supergravity theory in the ten-dimensional pp-wave background. There are many studies with respect to the classical solution of the supergravity theory or supersymmetry in the pp-wave background. However, it hardly understood about the property and the feature of the quantum correction or the renormalization in the pp-wave background. Especially, it was a problem about the regularization method in the calculation of the quantum correction for the pp-wave background. In terms of the path integral method [4] and the light-cone quantization method [3], I calculated the one-loop quantum correction of the scalar field in the pp-wave background. Then, I constructed the calculating method of the effective potential of the scalar field without above problem.

(4) Excitation of Kaluza-Klein mode in cosmology

Many authors paid attention to the Kaluza-Klein theory because this is inevitably requested when thinking about the fact that the consistency of superstring theory requires ten dimensions at least. Then, it was thought that the radius of the internal space was stabilized due to the damped vibration under the effective potential for the radius. In this case, it was necessary to clarify whether the effect of the resonance of non-thermal particle creation gave the influence to the problem of surviving Kaluza-Klein mode in the four-dimensional cosmology or not.

The idea of this work was given by the consideration concerning the dynamics of the internal space. It was shown that the one-loop quantum effect works effectively as a stabilization mechanism of an internal space. We analyzed the surviving Kaluza-Klein mode for several compactification models and discussed that the effect of the resonance of non-thermal particle creation could be negligible [8, 9].