# Research Experience


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It has been the aim of my research to deepen our understanding of various phenomena in the universe making free use of the universal laws of physics. In my opinion this is the real pleasure of theoretical physics and astrophysics. I have thus been working on cosmology and gravitation, focusing mainly on braneworld cosmology, string cosmology, Hořava-Lifshitz cosmology, dark energy and dark matter, modification of gravity at long distance and time scales, black hole entropy, and so on. In the following I would like to explain some of my main contributions to the field.

#### Braneworld cosmology

Cosmology has recently been acquiring greater importance not only as our attempt towards better understanding of the universe but also as an ultimate testing ground of high energy physics. I consider it of particular interest to continue testing the predictions and ideas from string theory, that is considered as a candidate for the theory of everything, through cosmology. From this point of view, braneworld cosmology is one of important attempts to test the idea of extra dimensions predicted by string theory.

In a 5-dimensional braneworld scenario proposed by Randall and Sundrum, I found an exact solution that represents a general homogeneous and isotropic universe on the brane [161]. The effect of the extra-dimension is encoded in a concrete term in the evolution equation of the 4-dimensional universe on a brane and I named it dark radiation, which is a standard terminology in the field now. After finding a homogeneous and isotropic cosmological solution, I developed a formalism to analyze cosmological perturbations [158]. In the 5-dimensional braneworld cosmology the number of independent components of cosmological perturbations is greater than that of the standard cosmological perturbations in 4-dimensions, and we need to solve a set of coupled partial differential equations for them. Fortunately, I discovered a master variable, from which all components of cosmological perturbations in the 5-dimensional braneworld cosmology are derived by simply taking derivatives. I then completed the formalism by deriving a master equation for the master variable. The exact background solution and the master equation for perturbations form the foundation of the braneworld cosmology and provide a method to compare the theory with observations. A number of research groups applied the formalism to actual computation and obtained observable results such as the spectrum of cosmic microwave background anisotropies.

In the field of braneworld cosmology, I also investigated the global spacetime structure of the above mentioned exact solution [159], analyzed the linearlized gravity in a gauge-invariant way [150, 149], discovered new solutions that take into account quantum effects [155, 153], studied extensions to higher dimensions [137, 135, 131, 129], and proposed a new braneworld cosmology based on tachyon condensation [148, 146].

I received the Young Scientist Award from the Physical Society of Japan for the series of works in the braneworld cosmology.

## String cosmology

The basic idea of string theory is as simple and ambitious as to describe everything in the universe by various oscillation modes of strings. For this reason it is often considered as the strongest candidate for the ultimate theory. Until 2002, however, an obstacle was standing in the way of string theory: there was no known solution in string theory that can describe the accelerated expansion of the 4-dimensional universe with the size and the shape of extra dimensions fixed. There were no-go theorems against construction of such a solution. Since there can be little doubt that the expansion of the universe is accelerating, the no-go theorems, if applicable to our universe, would drive string theory into a difficult situation. Fortunately, in 2003 such a solution was finally discovered by Kachru, Kallosh, Linde and Trivedi by evading the no-go theorems. When I heard about this breakthrough, I became certain that the age of string cosmology would come.

I thus started to work on early universe cosmology, in particular inflation, based on string theory. Why is our universe so big? Inflation can answer this question and also explain the origin of primordial fluctuations that seeded the rich structure in the universe such as galaxies and clusters of galaxies. However, while inflation is thought to be driven and ended by a field called inflaton, we do not really know what inflaton actually is. There are two kinds of strings in string theory: open string and closed string. A surface on which open strings end is a kind of soliton and is called D-brane. The possibility that a D-brane may be the origin of the inflaton has been attracting attention. Because of various structures in extra dimensions (such as warped throats due to fluxes of antisymmetric fields, other D-branes and anti D-branes, etc.), the D-brane moves in a nontrivial way. When the D-brane's potential energy changes slowly, our 4-dimensional universe may exhibit cosmic inflation.

A problem with the D-brane inflation is that an inflaton has a conformal (or an almost conformal) coupling to the spacetime curvature. This stems from the fact that the background spacetime is approximately anti de Sitter and thus the existence of the (almost) conformal coupling is rather universal. It had thus been thought that the contribution of this kind of coupling to the inflaton mass needs to be canceled with other effects by fine-tuning. With L. Kofman, however, I found that inflation can occur under a certain condition without need for a severe fine-tuning (conformal rapid-roll inflation) [126, 122, 116]. In this model it is not the inflaton but another field called curvaton that is responsible for generation of primordial cosmological perturbations. The role of the conformally coupled inflaton is to provide a background expansion suitable for the curvaton. Along with T. Kobayashi, I then proposed a model of curvaton based on a D-brane in warped extra dimensions, and showed that there are regimes of parameters consistent with observational data [115]. My collaborators and I investigated two types of curvaton models, one originated from a physical degree of freedom on the inflaton D-brane and the other from a degree of freedom outside the inflaton D-brane, and showed that they predict distinct inflationary observables [46].

In a paper with T. Kobayashi and S. Kinoshita [127], I also proposed a model of inflation driven by a D-brane wrapped over a part of extra dimensions. In this model we derived a relation between non-Gaussianities of cosmological curvature perturbations and the Euler number of a Calabi-Yau manifold. This work thus illustrates not only a concrete model building of the inflationary scenario within string theory but also the possibility that cosmological observational data may in principle tell us something about properties of extra dimensions. I also proposed a dark matter candidate from anti D-branes [138], and a reheating scenario based on brane motion [128].

## Cosmology based on Hořava-Lifshitz gravity

Gravity and particle physics are successfully described by general relativity and quantum field theory, respectively, in a vast range of scales. However, in extreme situations such as the beginning of the universe, both of them fail to work. We thus need a theory of quantum gravity.

I have been working on cosmology based on string theory, which is the strongest candidate for the theory of quantum gravity. However, string theory is not the only candidate. Actually, a gravity theory proposed by Hořava in 2009, often called Hořava-Lifshitz gravity has been thought to realize renormalizability and unitality and was recently proved to do so indeed. Thus Hořava-Lifshitz gravity is also a strong candidate for the theory of quantum gravity.

One day in 2009, I took one look at the Hořava's paper for the first time and knew instinctively that this theory would lead to a novel cosmology. What I noted was a property called anisotropic scaling, which is the essential reason why the theory is renormalizable. I soon found that the anisotropic scaling renders quantum fluctuations at short distances scale-invariant and thus thought that this may lead to a novel mechanism for generation of cosmological perturbations. I thus proposed a new scenario of the early universe that can solve the horizon problem and generate scale-invariant cosmological perturbations without need for inflation [118]. This scenario can be applied to all versions of Hořava-Lifshitz gravity that have been proposed so far.

Based on the so called projectable version of the Hořava-Lifshitz gravity, I also proposed a scenario that can mimic behaviors of dark matter without dark matter [114, 112], and a scenario that can amplify the amplitude of stochastic gravitational waves [117].

After publishing the series of works, I was invited to write a review article on cosmology in Hořava-Lifshitz gravity [101]. The article was selected as one of Highlights of 2010-2011 in the journal. I was then appointed as an Editorial board member of Classical and Quantum Gravity.

So far I have described some of my research subjects in which developments of gravitational theories at short distances led to novel views on our universe. Experimentally, we do not know how gravity behaves at distances shorter than about 0.01 mm. At such short distances, gravity may behave completely differently from what we naively expect. From theoretical viewpoints as well, many researchers consider it necessary to modify general relativity one way or another to treat gravity consistently as a quantum theory. In this sense gravity at short distances is one of frontiers in theoretical physics.

## Higgs phase of gravity

Gravity at cosmological scales is also considered as yet another frontier since gravity at such long distances has never been probed directly.

The latest observational data suggests that the universe today is mostly filled with unknown energy and matter. These energy and matter are called dark energy and dark matter, respectively, and it is thought that they fill more than 90 percent of the universe. Nonetheless, we do not know what they really are. Along with N. Arkani-Hamed, H. C. Cheng and M. Luty, I thus started to reconsider the question "Do we really need dark energy and dark matter?" When the perihelion shift of Mercury was discovered in the Nineteen Century, some people tried to explain this interesting phenomenon by introducing an unknown planet, so to speak dark planet. Some people even "discovered" it. As we all know, however, the right answer was not a dark planet but to change gravity, from Newton's theory to Einstein's general relativity. This was indeed the beginning of the success of the new theory. We thought that the mystery of the accelerated expansion of the universe might be similar. We thus started to ask "Can we change general relativity at long distance or/and time scales instead of introducing dark energy or/and dark matter?"

In the end we decided to apply the Higgs mechanism, that plays an important role in the standard model of particle physics, to gravity and reached a completely new idea called ghost condensation [142]. In ghost condensation the structure of the low energy effective field theory (EFT) is determined by the symmetry breaking pattern and thus general relativity is modified at long distance and time scales in a theoretically consistent way. The systematic method of construction of the low energy EFT that we developed is universal and thus can be applied or/and extended to different setups. For example, Cheung, Creminelli, Fitzpatrick, Kaplan and Senatore extended our construction of the EFT to a general homogeneous and isotropic background to construct what is currently known as EFT of inflation. The same kind of EFT was later applied to late-time acceleration to construct what is called EFT of dark energy. Also, Dubovsky applied the method to develop new classes of massive gravity theories.

I have been working on properties and applications of ghost condensation, such as the possibility for it to replace dark energy and dark matter [142], a new model of inflation [141], accretion to a black hole [139], the formulation of cosmological perturbation theory [132], the gauged version of ghost condensation as a partial UV completion [134], the consistency with the generalized second law [111] and the de Sitter entropy bound [55], and so on.

## Massive gravity

Spins and masses are among those important properties that characterize particles. It is easy to give a mass to a spin-0 particle, by simply adding a mass term to the Lagrangian of a scalar field. For a spin-1 particle, we know the Higgs mechanism and one can give a mass to a vector field by postulating a state that spontaneously breaks the gauge symmetry of the theory. Until very recently, however, we did not know whether we can give a mass to a particle with spin-2 in a theoretically consistent way.

Massive gravity, the possibility that the graviton, a spin-2 field, may have a non-vanishing mass, has a long history since Fierz and Pauli proposed a linear theory in 1939. However, in 1972 Boulware and Deser pointed out an instability at nonlinear level. Since then for a long time it had been thought that a graviton cannot have a non-zero mass. It took almost 40 years until de Rham, Gabadadze and Tolley finally found a theory of massive gravity, often called dRGT theory, that avoids the problem of the Boulware-Deser instability.

With a consistent theory of massive gravity found in 2010, it is natural to apply it to cosmology in order to solve the riddles of the universe such as cosmic acceleration. Dark energy is necessary if general relativity is correct. However, it may be unnecessary if the behavior of gravity is modified from general relativity at long distance or/and time scales. Along with collaborators, I thus investigated cosmological solutions and their stability systematically. Concretely, we first found a homogeneous and isotropic, self-accelerating cosmological solution [93], analyzed gauge-invariant cosmological perturbations around it [92], discovered a new type of nonlinear instability [89], found a new class of cosmological solutions that is expected to produce statistical anisotropy of perturbations [88, 81], and so on. We have also been studying extensions of dRGT theory. For example, by modifying the so-called quasidilaton theory, we found a homogeneous and isotropic, stable self-accelerating solution [77, ?]. In 2013, I acted as the editor of "CQG Focus Issue on Massive Gravity" in Classical and Quantum Gravity to summarize the progresses and future prospects of the field.

In 2014 I received the Lagrange Award from Institut Lagrange de Paris for the series of works on massive gravity and other subjects of gravity.

More recently, along with A. de Felice, I proposed a new theory of massive gravity (minimal theory of massive gravity) [61, 58]. This theory has only two physical degrees freedom and serves as a stable nonlinear completion of the above mentioned self-accelerating cosmological solution that I had found in dRGT theory with other collaborators [93]. From the observational point of view, it was found that this theory can fit the recent data of redshift distorsion meassurement better than the standard $\Lambda$CDM [48].

## Black hole entropy

The theory of black holes has a collection of properties analogous to thermodynamics and it is often called black hole thermodynamics. I have been interested in black hole thermodynamics and, in particular, the microscopic origin of black hole entropy.

With W. Israel, I revisited a long-debated problem in the brick wall model for the origin of black hole entropy [169]. In this model, black hole entropy is considered to be originated from a thermal atmosphere near the black hole horizon. However, many people including 'tHooft, who had proposed this model, pointed out the problem of strong backreaction due to large positive energy and considered it as a fatal defect of this model. Contrary to the " lore ", by identifying the correct ground state of the system, we showed that the problematic large positive energy is canceled by negative energy of the ground state and that the backreaction is actually weak enough.

I have also worked on various other aspects of black hole entropy. These include validity of the generalized second law [177, 163], other proposals for the origin of black hole entropy such as D-brane description in superstring theory [176] and entanglement entropy [175, 171, 170, 165], extensions of the first law of black hole thermodynamics to general covariant theories of gravity [168] and to dynamical processes [167, 164], and so on.

## Other subjects

- With collaborators including experimentalists, I studied high energy phenomena beyond the Planck scale by using polarization data of gamma-ray bursts. If the dispersion relation of photons receive corrections due to quantum gravity effects then the propagation of photons is modified. For example, if the CPT is broken at extremely high energy then polarization of photons from gamma ray bursts will be depleted. This effect is locally negligible but can be observable if integrated over cosmological distances as photons travel. In other words, if polarization of a gamma ray burst at a cosmological distance is observed then it implies that the CPT symmetry holds at high energy. By using the observational data we have shown that the CPT symmetry holds at energies all the way up to at least $10^{15}$ times the Planck scale [87]. This was the most stringent bound on the CPT violation at that time and gave a strong constraint on quantum gravity theories such as loop quantum gravity.

- Magnetic fields in the universe are observed at various scales. Recently a lower bound on the magnitude of magnetic fields in void regions were obtained by observation of TeV and GeV gamma rays. Along with T. Fujita, I thus started to work on scenarios of magnetogenesis during cosmic inflation. We then obtained a universal upper bound on the scale of inflation from the observational lower bound on the magnitude of the magnetic field, independently of details of theories [91]. Also, motivated by the suggestion in the literature that supercurvature modes of magnetic field may help magnetogenesis in open inflationary scenarios, we studied the $U(1)$ gauge field with unbroken or broken gauge symmetry in open de Sitter spacetime and proved that there is no supercurvature mode [72]. These results provide conditions to be imposed on early universe scenarios of magnetogenesis. Also, by taking into account possible nonlinear interactions of the $U(1)$ gauge field and its non-minimal coupling to gravity, I found a family of stable exact solutions that represent a homogeneous universe with a finite magnetic field [47].

- Rich structures in the universe such as galaxies and clusters of galaxies are thought to be formed due to gravitational instability from quantum fluctuations generated during inflation. I have been studying inflationary cosmological perturbations by using both perturbative [109, 116, 122] and non-perturbative (gradient expansion) [123, 105] approaches complementarily.

- Because of their extremely weak interactions, gravitational waves are expected to play important roles in probing the early universe era before recombination of hydrogen atoms. There are many observational projects and theoretical ideas to detect gravitational waves and to use them as probes of the universe and new physics. I worked on ideas to test cosmological scenarios such as inflation driven by a pseudo scalar [85], modified cosmic expansion due to quantum gravity effects [117] and massive gravity [86] by stochastic background gravitational waves.

- There are a number of mysteries in cosmology, such as dark energy, dark matter, inflation as well as initial singularity and cosmic magnetic field. Some of those mysteries may be solved by modification of gravity. On the other hand, modification of gravity is allowed only to the extent that is consistent with experiments and observations. The parameterized post-Newtonian (PPN) formalism can be applied to various gravity theories and has been playing important roles in interpreting results of gravitational experiments at the solar system scales in a universal way. Along with collaborators, I pointed out that the conventional PPN formalism cannot be applied directly to the low energy limit of Hořava-Lifshitz gravity. We then extended the formalism by introducing a new parameter to make it possible to compare the theory with gravitational experiments at the solar system scales [74, 90].

- In quantum gravity the concept of time is not fundamental but is emergent in the sense that it is encoded in correlations among observables. In order to understand the origin of time in the system with gravity, J.-P. Uzan and I proposed a novel mechanism by which a Lorentzian theory emerges from a Riemannian, i.e. locally Euclidean, theory [84, 83]. Based on this scenario, I proposed a new theory of gravity that is power counting renormalizable [82]. The theory was later proved to be renormalizable by other authors.

- Superstring theory is not only a strong candidate for the ultimate theory of the universe but also serves as a useful tool to analyze gauge theories. This is because the AdS/CFT correspondence often translates difficult problems in gauge theories to less difficult problems in gravity. Along with collaborators, I constructed a black hole spacetime that is dual to a situation closely related to the actual QGP experiments [124, 120]. This is an example of the AdS/CFT correspondence in a time-dependent situation.

# Future Research

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Cosmology has been rapidly developing, based on precision observational data. It is fair to say that many parameters describing our universe have been determined, or at least are in the process of being determined, with good precision. However, the physics behind the values of these parameters is still hidden in a veil of mystery. For example, we do not know what dark energy and dark matter really are, although our universe is thought to be filled mostly with them. Also, what made our universe so big? This question can be addressed by cosmic inflation, but again we do not know the physical origin of the inflaton field driving inflation. Three great mysteries, dark energy, dark matter and inflation, are standing in the way of cosmology which boasts precision observational data. I will continue tackling the mysteries of the universe by using every possible means such as general relativity, statistical physics, particle physics and superstring theory.

One of the greatest aims of theoretical physics is to construct the theory of quantum gravity. This is an attempt to unify quantum mechanics and Einstein's theory of general relativity. I expect that in the process of finding the theory of quantum gravity, research of cosmology and black hole entropy will play important roles. Hence, I will cope with any problems to understand the origin and the dynamics of the universe and black holes with great interest, including all research fields in which I have been working. If we take into account the fact that superstring theory, as a strong candidate for the theory of everything, is gradually revealing its non-perturbative, whole structure and if we compare this exciting situation with the history of the development of quantum mechanics, it is probably very effective to tackle concrete problems like cosmology and black hole entropy. I thus strongly believe that cosmology and black hole entropy will play as important a role in the development of quantum gravity as the black body radiation and the hydrogen atom did in the development of quantum mechanics.

Before explaining concrete research themes, I would like to state my attitude as a theoretical physicist. In order to make robust predictions, there are two approaches at least. One is to develop quantum mechanically stable arguments, based on symmetry or symmetry breaking pattern in a low energy effective theory. The other is to go back to a more fundamental theory and to extract its predictions. I will proceed with my research by using the two approaches complementarily.

In the following, I would like to explain some of my future research themes, focusing particularly on "cosmology based on quantum gravity", "Cosmological constant problem and Higgs mechanism for gravity" and "Black hole entropy and information loss problem".

### Cosmology based on quantum gravity

In our universe physical phenomena at various scales occur constantly, having mutual influence on each other. I consider it necessary for physics at the largest scales, i.e. cosmology, to be connected with physics at the shortest scales. This is because the extremely high energy state of the early universe makes microscopic physics essentially important. At the beginning of the universe, both gravity and quantum effects are significant and, as a result, both general relativity and the conventionsl quantum field theory break down. For this and many other reasons, we need a theory of quantum gravity that can describe gravity in a quantum mechanically consistent way. I expect that candidate theories for quantum gravity, such as superstring theory and Hořava-Lifshitz gravity, will provide us with hints towards solutions of the mysteries in cosmology. Cosmology based on quantum gravity should play important roles in our understanding of the universe.

I will develop my research on cosmology based on quantum gravity and aim at a theoretically consistent and observationally viable cosmological scenario. In model building I will pay attention to observables such as B-mode polarization and (e.g. equilateral-type) non-Gaussianities of cosmic microwave background anisotropies. By linking theoretical ideas with observations and experiments, I will continue pursuing the possibility that observations at the largest scale may unravel the physics at the shortest scale.

Concretely, the subjects that I am currently interested in include, but are not restricted to, inflationary model building in string theory, dynamics of extra dimensions and gravity in braneworld scenarios, the reheating problem in multi-throat scenarios, cosmology based on Hořava-Lifshitz gravity, and so on. For example, I consider it necessary to investigate general properties of warped compactifications in string theory from higher dimensional viewpoints. How do brane motion and bending act as gravitational sources that make extra dimensions curved? As a result, what kind of effects do extra dimensions induce on our 4-dimensional universe on the brane? Can we probe extra dimensions by these effects? We need to answer these questions.

## Cosmological constant problem and Higgs mechanism for gravity

The cosmological constant (cc) problem is one of the most difficult problems in theoretical physics and cosmology. There are two aspects of the cc problem. The first is "Why small?" The observational upper bound on the cc is smaller than what is naively expected quantum mechanically by 120 orders of magnitude. At present there is no theory that can convincingly explain this small value. For this reason, some researchers show a tendency to rely on the anthropic principle. However, I consider it premature to give up seeking a solution without the anthropic principle. In the past, along with L. Randall, I proposed a cosmological model towards a solution to the cc problem. We scceeded in making the cc sufficiently small. The remaining problem is how to reheat the universe. Even though we can make the cc small, we would end up with an empty universe if there was no reheating. Our model thus needs to be extended so that the universe is sufficiently reheated, with the cc kept small. If successful, this will be a significant progress towards a solution to the cc problem. We should not give up attempting difficult problems.

The second aspect of the cc problem is "Why not zero?" and "Why now?" This is nothing but one of the three great mysteries of the universe, dark energy. Although dark energy is thought to fill more than 70% of the present universe, we do not know what it really is. This situation makes us feel that a hint for new physics may be hidden in gravity at cosmological scales. Evidences for dark energy so far are based on indirect observations of gravity at long distance and time scales but gravity at such scales has never been meassured directly. Along with collaborators, I therefore proposed a scenario called ghost condensation to modify general relativity at long distance and time scales. Ghost condensation is the simplest realization of an analogue of Higgs mechanism in gravity and provides a way to break a part of diffeomorphism invariance spontaneously in a theoretically consistent way. Considering the important roles of Higgs mechanism in the standard model of particle physics, this (and its extensions) may be the only way to modify gravity at long distance and time scales from low energy effective field theory viewpoints. By further developing this idea, I would like to make efforts to understand the mystery of dark energy. In particular, I consider it important to investigate nonlinear dynamics. While ghost condensation is known to behave as dark energy and/or dark matter for a homogeneous and isotropic background and linear perturbations around it, nonlinear dynamics is not well understood. Through the investigation of nonlinear dynamics, there is a possibility that ghost condensation can be distinguished from dark energy and dark matter observationally.

Also, I aim to derive theories of massive gravity by means of spontaneous symmetry breaking. Recently massive gravity has been attracting a great deal of interest. However, theories of massive gravity known so far have low cutoff scales and their regime of validity is narrow. In particular, they cannot be applied to the early universe directly. By the method of spontaneous symmetry breaking, I would like to improve this situation in massive gravity.

Properly speaking, it may be the case that the second cc problem, i.e. the mystery of dark energy, should be studied only after the first problem, i.e. the "why small" problem, is solved. On the other hand, recent developments in dark energy surveys are worthy of note. I thus consider it a rational strategy to investigate the second problem by the bottom-up approach while studying the first problem by the top-down approach. By using the two approaches complementarily, I will continue my research towards a simultaneous solution to the two cc problems.

### Black hole entropy and information loss problem

It is well known that research on hydrogen atoms played an important role in the history of quantum mechanics. It think it is black holes that will play similar roles towards construction of the theory of quantum gravity. Actually, I think that the so-called AdS/CFT correspondence, which is one of the most important developments in superstring theory in recent years, would not have been discovered without intensive theoretical research on black holes. I believe that the theory of black holes will continue to be one of important research themes.

Microscopic black holes formed in the early ulniverse are thought to lose their masses by Hawking radiation and thus may eventually evaporate. What happens to the information inside a black hole if it evaporates? This is the information loss problem. If the information inside an evaporating black hole is lost then it implies a breakdown of the unitarity of the quantum mechanical system by gravitational effects. For this reason, understanding this problem is expected to be a cornerstone for our attempt to unify the quantum theory with gravity. Many researchers including myself think that information will not be lost. However, up to now it is not clear how information is restored.

I would like to tackle the information loss problem through research on black hole entropy. It is expected that black hole entropy should reflect the number of microscopic degrees of freedom and also the amount of information stored in a black hole. The entanglement entropy that I considered as a candidate for the origin of black hole entropy is relevant to the information theory. I expect that black hole entropy and quantum entanglement will be important keys towards a solution to the information loss problem.

### Other subjects

Besides the research topics that I explained so far, I would like to expand other subjects that I have been working on, such as perturbative and non-perturbative (gradient expansion) studies of inflationary cosmological perturbations, large scale magnetic fields in the universe, applications of the guage/gravity correspondence, constraints on quantum gravity from astrophysical phenomena such as gamma ray busts, tests of gravity at solar system scales, and so on. In doing so, I will act according to the circumstances in theories and observations/experiments.

If I self-analyze my style of research in the past, there is a tendency that new developments in fundamental theories inspired me to find novel pictures of our universe. Some of such examples are: a new cosmological solution in the Randall-Sundrum braneworld scenario, the conformal rapid-roll inflation inspired by the discovery of an accelerating solution in string theory, a new mechanism of generation of superhorizon cosmological perturbations in a renormalizable theory of gravity, a new self-accelerating cosmological solution from developments in massive gravity, and so on. By continuing this style of research, I would like to pursue the true picture of our unvierse from the viewpoints of fundamental theories. I will also make effort to extend this style to broaden our knowledge on fundamental theories through attempts to solve the mysteries in cosmology. I will keep these in mind and cotinue research, in cooporation with colleagues and collaborators.