Research Accomplishments: I have been interested in gravity theories, in matter theories, and in the relation between them. I have been investigating these topics from both theoretical and observational aspects in the context of cosmology. The first set of our accomplishments is on the observational consistency of recently proposed gravity theories, while the second is on the proposal for the interaction between inflaton and matter particles.

■ To explain the observational results of galaxies, type Ia supernovae and the cosmic microwave background (CMB), we need dark components of the universe, dark matter and dark energy, in the context of general relativity (GR). If we do not confine ourselves to GR, such unknown components may be understood by alternative theories of gravity, where the gravitational force on cosmological scales deviates from GR. There is a recently proposed gravity theory called bigravity, possessing massive gravitons in addition to ordinary massless gravitons and modifying the gravity law at large scales. Bigravity is composed of two metrics, one of which is understood as the geometrical description of spacetime, and the other is some matter with the nature of spin-2. We examined the consistency of bigravity with the inflation scenario, which is successful in describing the early stage of the universe, and with the recent CMB observations.

Stability and cosmic no-hair conjecture of de Sitter solutions in bigravity We investigated de Sitter solutions, which approximates the inflationary universe, in a minimal model of bigravity. We found the unique stable branch of de Sitter solutions by examining the condition for the absence of the Higuchi ghost, which causes the instability in massive modes on de Sitter spacetime. Cosmic no-hair conjecture, which claims that the classical anisotropy decays during inflation, should hold to explain the isotropy of CMB. We confirmed that the conjecture holds in bigravity. [discussed in Publication 5. Please see List of Publications.]

Primordial gravitational waves in bigravity Primordial gravitational waves, the gravitational waves (GWs) generated during inflation, have not been detected yet but expected to be found through the observation of the CMB polarization and/or through the space-based gravitational interferometers in the near future. We calculated primordial GWs in bigravity and found out about the feature of their spectrum, such as the approximate flatness and the slight enhancement at large scales. [Publication 4]

Curvature perturbations generated during inflation in bigravity Curvature perturbations generated during inflation have been observed through temperature fluctuations of CMB. We calculated primordial curvature perturbations and evaluated an important observable constrained from above by the CMB observations, the tensor to scalar ratio, in bigravity. We concluded that bigravity is consistent with the current observational constraint from CMB and can be verified by the improvement of the observations. [Publication 3]

■ The matter sector is composed of Standard Model (SM) particles at the current time, and their interaction is well-investigated through the collider experiments. The SM particles were dissipated during inflation even if they existed before inflation, and therefore, they should be created through the decay of the scalar field driving the inflation, inflaton. The interaction between inflaton and the SM particles is difficult to be verified by the experiments since the typical energy scale during/just after inflation $\sim 10^{16}$ GeV is much higher than the energy we can reach now ~10^4 GeV. There is another way to inspect such interaction through the observation of CMB and of GWs since the interaction can affect the observable quantities.

Derivative interaction between inflaton and fermions At the current stage, where we do not know anything about the interaction between inflaton and SM particles, there is no reason to restrict the interaction to the simplest one since some new dominant phenomena may arise from more complicated interactions. The straightforward way to examine the effect coming from the inflaton-matter interaction is that we write down all possible interactions, calculate observable quantities and compare the result with the observations, which results in the constraint on the coupling constants appearing in the Lagrangian. Thus, the first step for the achievement is the construction of possible interactions. In many literatures, the extension of bosonic interactions has been discussed and is now successful, while the interactions including fermions were less discussed and there was no standard formulation for the construction.

We proposed how the interactions between bosons and fermions can be extended to include derivatives without spoiling the theoretical consistency, such as the freeness from extra d.o.f. causing the ghost instability and the unique time evolution of the system. It was discussed in the systems only with time dependence first [Publication 2], and the result was applied to finding derivative interactions in Lorentz covariant systems, where a boson and a fermion are considered as inflaton and a fermion in SM, respectively [Publication 1].