Research Plans: I would like to improve the results of the project on the interaction between inflaton and fermions and to find viable derivative interactions through observational results. As another direction, we are examining gravity theories with bounded Ricci scalar, especially focusing on the bounded nature.

Construction of the Lagrangian including derivatives of fermions on curved spacetime

We have proposed Lorentz covariant derivative interactions between inflaton and a fermion, but the background was flat, and thus, we would like to improve them into those on curved spacetime. However, the inclusion of gravity is a bit tricky since, on flat spacetime, we have eliminated the ghostly extra d.o.f. by regulating the combination of the derivative interaction terms so that constraints for fermions are obtained. To avoid the ghost instability, we have to find the suitable combination of derivative interaction terms even when the gravitational d.o.f., involved in the Hamiltonian analysis, are present.

For the purpose, first, we should concentrate on a simpler version, fermions on curved spacetime (w/o scalar fields,) since it has not generally been well-understood. Such an example can be constructed by making use of the conformal transformation, e.g., the Lagrangian of Ricci scalar with a conformal factor including scalar quantities made of fermions results in the addition of Einstein-Hilbert Lagrangian and the matter Lagranginan of fermions with (non Dirac-type) derivative terms coupled to gravity in Einstein frame. We will perform the Hamiltonian analysis for such systems and clarify the way to have healthy Lagrangians where fermions and gravity are coupled. The use of the disformal transformation, an extension of conformal transformation, will lead to an even larger class of derivative interaction terms in the Lagrangian. We aim at constructing covariant Lagrangians with both of scalar fields and fermions on curved spacetime in a similar manner.

Observational tests and predictions of the proposed interactions between inflaton and fermions

The interaction between inflaton and fermions can affect observable quantities. For instance, since the three point function of the inflaton fluctuations, non-Gaussianity, is not normally generated at the tree level for the inflation driven by a single field, the interaction between inflaton and SM particles can contribute to it at leading order through loop effects. The non-Gaussianity is constrained from the observations of the temperature fluctuations of CMB, and we would like to clarify the allowed values for the coupling constants of the proposed interactions through the comparison with the CMB observation.

Even after inflation, such interactions can play an important roll. At the end of inflation, the decay process of inflaton into SM particles occurs through the interactions between inflaton and SM particles and are highly dependent on the details of the interactions. We would like to analyze the particle creation process, taking into account the proposed derivative interactions between inflaton and fermions. Through the analysis, we will evaluate the temperature at which the particle creation occurs, the duration of the process, and the evolution of the matter energy density during the particle production. The evolution of the matter energy density determines the time evolution of spacetime, and the change of the expansion rate during the particle creation is imprinted on the spectrum of the primordial GWs as the different amplitudes for different frequency bands. Thus, we will put the constraint on the coupling constants of the derivative interactions by comparing the primordial GW spectrum we calculate with the GW observations by LISA and DECIGO.

Cosmology in f(R) gravity theories with bounded Ricci scalar

The Lagrangian of GR is made of the Ricci scalar *R* and the gravitational constant *G*, the coupling constant between gravity and matter. In the context of quantum field theories, the coupling constant is not really a constant but rather a "running coupling constant," changing depending on the energy scale we consider. The renormalization group method, in general, gives the relation between the energy scale, approximated by the field strength, and the coupling constant. This fact implies the boundedness of the field strength, e.g., in pure Yang-Mills theories with SU(*N*), and thus motivates the boundedness of the Ricci scalar in gravity theories, which can be realized by considering a bounded function of *R* as the gravitational Lagrangian. This concept is also interesting in that they can avoid the initial singularity problem in the early universe. The Lagrangian with a general function of *R*, named *f(R)* gravity theory, has been considered to realize the recent accelerated expansion of spacetime, though they usually considered specific unbounded functions as an extension of GR.

We would like to clarify the general feature of the "bounded" theories of gravity. We are now going to discuss FLRW solutions of bounded *f(R)* gravity theories in vacuum and to investigate the general structure of the phase space determining the time evolution of the spacetime. Interestingly, the phase space seems to accept the solutions possessing both inflationary phase and current accelerated expanding phase. We would then like to include matter contribution, to evaluate the change of the phase space and to find out whether the time evolution of the spacetime matches the current understanding of the universe. The stability of the solutions are also to be examined for the viability of the scenario.