論文の内容の要旨

Gravitational effects on inflaton decay at the onset of reheating

（再加熱初期における インフラトン崩壊に対する重力の効果）

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In the early universe, there exists a phase after the cosmic inflation called reheating, when the energy density of the inflaton is converted to that of light particles and these particles subsequently thermalize. At the onset of this reheating era, the oscillation of the inflaton generically induces oscillation modes in the expansion rate and the size of the universe due to the coupling between the inflaton and gravity, and these oscillation modes lead to the production of those particles coupled to gravity. The present thesis is devoted to the investigation of this production mechanism and its phenomenological consequences.

In the present thesis, we first point out that this mechanism exists even in the setup with theoretically minimal requirements, or the one where only the Einstein gravity and a canonical inflaton dominate the dynamics. This production process is interpreted as a two-body annihilation of the inflaton, and it brings about nonnegligible consequences to the present universe, for example as the dark matter. It is also shown that graviton production necessarily occurs by the same mechanism.

When the inflaton is nonminimally coupled to gravity, on the other hand, more violent oscillation of the expansion rate and nontrivial phases often emerge. In order to analyze the dynamics, a novel method is proposed in which an "adiabatic invariant" is constructed. This enables one to extract the oscillation modes in the expansion rate and to estimate the averaged expansion law of the universe, and as a consequence to understand the background dynamics of the models and the resulting particle production.

This method is applied to several observationally motivated models with the inflaton nonminimally coupled to gravity. Concretely, we analyze those models where the inflaton ϕ is coupled to the Ricci scalar R as $f(\phi)R$, and those where the inflaton is derivatively coupled to the Einstein tensor $G_{\mu\nu}$. In one example of the former, it is found that the oscillation mode of the expansion rate and the resulting particle production is interpreted as the emergence of a "decay" channel of the inflaton, in contrast to annihilation, which

is strong enough to complete the inflaton decay. In another example of the former, it is pointed out that heavy particle production is possible during the nontrivial phase brought about by the nonminimal coupling to gravity. The latter case, on the other hand, turns out to have totally different features from the previous models. The violent oscillation of the expansion rate of the universe induces instabilities associated with the sound speed. In addition, we point out the possibility of graviton resonant production, which occurs if such a violent oscillation survives the backreaction from the (expectedly) explosive particle production triggered by the instability. These studies shed light on the rich phenomenology of gravitational couplings of the inflaton at the onset of reheating.