論文の内容の要旨

論文題目

The Effective Masses of Scalar Fields in the Radiation Dominated Universe
(輻射優勢宇宙におけるスカラー場の有効質量)

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Effective mass plays important roles in the models of the early Universe. For example, thermal effective mass may be the origin of some cosmological phase transitions like electroweak symmetry breaking. Another example is that the so-called Hubble-induced mass, which is generated by supergravity effects during inflation, is a key for the Affleck-Dine baryogenesis, the adiabatic solution for the cosmological moduli problem and so on.

In this thesis, we consider the effective masses of scalar fields in the radiation dominated (RD) Universe. We in particular pay attention to the effective mass of a weakly coupled scalar field ϕ which interacts with the thermal plasma via Planck-suppressed interactions. Using the techniques of thermal field theory, we evaluate such an effective mass.

First, we consider a toy model in which scalar fields or fermion fields consist of the thermal bath and these thermal fields generate the effective mass for ϕ. Here, we assume that ϕ interacts with the thermal fields through a non-minimal Kahler potential. This Kahler potential leads to the coupling between ϕ and the kinetic term of the thermal fields. Then, the effective mass of ϕ is expressed as a thermal expectation value of the kinetic term. We evaluate this quantity based on thermal field theory, relying especially on the quasi-particle approximation. The resultant effective mass of ϕ is of the order of the Hubble scale in the RD era times the yukawa coupling of the thermal fields and divided by the effective number of the relativistic degrees of freedom in the thermal bath.

If we consider a more realistic thermal bath, there will be gauge fields and gauge interactions. However, we cannot apply the above procedure directly since the above procedure implicitly assumes only the yukawa interactions. In order to overcome this situation, we improve our procedure. The outline of the new procedure is as follows.

1. Rescale the chiral (matter) fields in order to have the canonical kinetic term for the chiral fields.
2. Absorb the ϕ dependences into the yukawa couplings in order to have the global supersymmetric scalar potential and fermion interactions.
3. The same rescaling of the chiral fields induces a rescaling anomaly. We absorb this induced ϕ dependence into the gauge couplings.
4. Now, we have rescaled yukawa and gauge couplings. The kinetic terms, the scalar potential and the fermion interactions become the global supersymmetric forms.
5. Using the rescaled couplings, we evaluate the free energy of the system.
6. Finally, we can easily read off the effective mass for ϕ from the free energy.

As a demonstration, we evaluate the effective mass for ϕ generated from the minimal supersymmetric standard model (MSSM) plasma in which both the yukawa interaction and the gauge interactions are included. We derive a complete analytic expression for the effective mass for ϕ at leading order of the couplings. The resultant effective mass for ϕ is of the order of the Hubble scale in the RD era

times some powers of the yukawa and gauge couplings. For typical parameter sets, we find that the magnitude of the effective mass-squared for ϕ is about (0.01~0.001)×Hubble scale-squared.