論文内容の要旨

論文題目 Dynamics of Peccei-Quinn Field in the Early Universe
(初期宇宙における Peccei-Quinn 場のダイナミクス)

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In this thesis, we consider the cosmology of the Peccei-Quinn models paying particular attention to the dynamics of the scalar fields which have $\mathrm{U}(1)_{\mathrm{PQ}}$ charges. Cosmological consequences largely depend on the dynamics of such scalar fields in the early universe. If $\mathrm{U}(1)_{\mathrm{PQ}}$ is restored at some epoch, the $\mathrm{U}(1)_{\mathrm{PQ}}$ charged scalar fields start to oscillate later. Such oscillating scalar fields may dominantly decay into relativistic axion particles which become a dark radiation component of the universe, whose energy density is tightly bounded. We clarify in what circumstances, the axion overproduction is avoided taking effects from the thermal plasma in the universe into account. We show that owing to the thermal dissipation effects, the axion overproduction can be avoided even when the scalar field once dominates the universe. We also consider the case where the $\mathrm{U}(1)_{\mathrm{PQ}}$ symmetry is always broken in the history of the universe by field values of scalar fields. In such a case, a severe constraint is imposed on the Hubble scale during inflation. We propose two new scenario which relax this constraint. In the first scenario, we consider a peculiar scalar motion in the expanding universe, which we call as a pseudo scaling solution. We show that if the $\mathrm{U}(1)_{\mathrm{PQ}}$ charged scalar field once obeys the pseudo scaling solution, the constraint on the inflation scale is likely to be relaxed without the symmetry restoration, which is indispensable for models with the domain wall number greater than unity. In the second scenario, we consider the dynamics of multi $\mathrm{U}(1)_{\mathrm{PQ}}$ charged scalar fields. We find a simple mechanism which relaxes the bound on inflation scale and avoids the symmetry restoration. We apply this mechanism to a DFSZ Higgs inflation scenario and show that mechanism can work. In both scenarios, the dynamics of the $\mathrm{U}(1)_{\mathrm{PQ}}$ charged scalar fields play important roles.