論文内容の要旨

Particle-Physics Phenomenology and Cosmology of Gauge Mediated Supersymmetry Breaking Models

(超対称性の破れのゲージ伝達模型における素粒子現象論および宇宙論)

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Supersymmetric extension of the Standard Model is one of the most motivated candidate for beyond the Standard Model. Supersymmetry is a symmetry which transforms bosons into fermions and vise versa, and it is thought to play crucial role to answer the hierarchy between the weak scale and the scale of grand unified theory (GUT) or the Planck scale. In addition, it naturally provides the lightest superparticle (LSP) as a good candidate for the dark matter of the universe.

The phenomenological and cosmological feature of a supersymmetric Standard Model depends on how supersymmetry is broken and how such breaking effects are mediated to the particles in the supersymmetric Standard Model. Hence, to determine the mediation mechanism of supersymmetry breaking is the most important task to construct a supersymmetric Standard Model.

Among the mediation mechanism proposed so far, gauge mediated supersymmetry breaking model is one of the most prosperous mediation mechanism. In the model, supersymmetry breaking in the "hidden" sector is mediated to the supersymmetric Standard Model via standard $SU(3)_c \times SU(2)_L \times U(1)_Y$ gauge interactions. Since gauge interactions are independent of the flavor the supersymmetric Standard Model, the infamous supersymmetric flavor problem is absent automatically. This is one of the main phenomenological advantage of gauge mediated supersymmetry breaking model. It is also remarkable that all the scalar particles except for Higgs bosons are guaranteed to have positive masses squared, while electroweak symmetry breaking occurs naturally due to the right size of radiative corrections.

From a theoretical point of view, gauge mediation model is also attractive, since it is free from the details of unknown fundamental theory beyond the Planck scale. Namely, gauge mediation model hardly depends on the non-renormalizable interactions at the fundamental scale. This is remarkable when we compare it to the situation in gravity-mediation model where its predictions highly depend on such uncontrollable non-renormalizable interactions.

Another distinctive feature of gauge mediation model is the existence of light stable

gravitino. Such gravitino is known to lead very distinctive signals in collider experiments. In addition, stable gravitino may be a good candidate for the dark matter. However, as a solution to the dark matter, stable gravitino faces some difficulties. Thermal history of cosmology with such stable gravitino is completely different from cosmology with unstable gravitino, and in some cases, such stable gravitino leads to stringent constraint on the reheating temperature after inflation.

In this thesis, we study phenomenological and cosmological aspects of gauge mediated supersymmetry breaking model. In the former part of this thesis, we review the distinctive features of phenomenological aspect of gauge mediated supersymmetry breaking model. In addition, we also discuss new insights on the little hierarchy problem in gauge mediation model.

In the latter part of this thesis, we discuss cosmological aspect of gauge mediation model. If gravitino is light and stable, the upper bound on the reheating temperature T_R is known about 10^6 GeV when $m_{3/2} \simeq 10\,\mathrm{MeV}$ for instance, and it even reaches $T_R \lesssim 10^3\,\mathrm{GeV}$ in the case of the light gravitino $m_{3/2} \lesssim 100\,\mathrm{keV}$. Such stringent upper bounds on the reheating temperature is unpleasant when we consider an origin of baryon asymmetry, such as thermal Leptogenesis, which requires very high reheating temperature.

However, we show that by pursuing a gauge mediation model which has stable vacuum and no exotic stable particles (other than gravitino), we can reach a model where the reheating temperature is free from the above upper bounds. There, the model includes a scalar particle which has very flat potential which causes "mini" inflation well after inflation and the reheating. Then, the problematic gravitino is diluted away and the above constraints can be evaded for $100\,\mathrm{keV} \lesssim m_{3/2} \lesssim 10\,\mathrm{MeV}$. Therefore, we find that the problem of gravitino and the reheating temperature is not a problem any more, and the gauge mediated supersymmetry breaking model is also viable from the point of view of cosmology.

As another possibility, we also discuss another gauge mediation model which has peculiar spectrum with stable vacuum. This model is interesting since we can achieve very light gravitino with mass range $m_{3/2} \lesssim 16\,\mathrm{eV}$ where gravitino is known to cause no cosmological problem. We show that the requirement $m_{3/2} \lesssim 16\,\mathrm{eV}$ leads to the stringent upper bounds on the masses of the other supersymmetric particles; 1.1 TeV, 320 GeV, 160 GeV, 5 TeV, 1.5 TeV and 700 GeV for gluino, Wino, Bino, squarks, left-handed sleptons and right-handed sleptons, respectively. We also show that the light messenger slepton is predicted to have the mass of 10-50 TeV, and hence it would be an interesting dark matter candidate.

Through these studies, we confirm that gauge mediation models can be consistent with cosmology as well as phenomenology.