論文内容の要旨

「論文題目」

Inflation Models in Super Gravity Theory: Problems and Solutions

（超重力理論でのインフレーション模型：問題点とその解決）

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The supersymmetric standard model is a very attractive candidate for the beyond standard model. At the same time, it is believed that inflation era must exist at a very early universe, since it solves shortcomings of the hot Big Bang universe and the quantum fluctuation of the inflaton field can explain the observed fluctuation of the Cosmic Microwave Background (CMB). However, more detailed studies reveal that various things should be discussed closely. Especially it has been revealed that we have many disputable points about gravitino which is the superpartner of the graviton and becomes massive by the super Higgs mechanism as $m_{3/2} \approx O(\mathrm{eV})$ - $O(100)\mathrm{TeV}$.

The disputable points come from a fact that the gravitino yield, that is a ratio of the gravitino number density and the entropy density, is severely bounded from above. The roots of the constraints depend on the gravitino mass, that is, how the SUSY breaking is mediated to the Minimal Supersymmetric Standard Model (MSSM) particles. The roots are briefly summarized as the following:

1. ***Gauge mediation***: $m_{3/2} \leq O(10)\mathrm{GeV}$

In this case, the gravitino is the Lightest Supersymmetric Particle (LSP) and a (warm or cold) dark matter candidate. For free-streaming of the dark matter not to spoil the structure formation, the warm dark matter density is constrained and the observed cold dark matter density: $\Omega_{DM} h^2 \cong 0.105$ gives a constraint for the cold gravitino dark matter.

2. ***Gravity mediation:*** $m_{3/2} \cong O(100)\text{GeV} - O(10)\text{TeV}$

When the gravitino mass takes these values and the gravitino is unstable, its life time scale is longer than $O(10)\,\text{sec}$ which is the time scale of the Big Bang nucleosynthesis. Energetic particles are produced from the decay of gravitinos and destroy the synthesized light elements. Not to spoil the success of the Big Bang nucleosynthesis the gravitino yield is bounded from above.

3. ***Anomaly mediation:*** $m_{3/2} \cong O(100)\text{TeV}$

In this case, it decays much before the Big Bang nucleosynthesis. A constraint on the gravitino yield comes from its decay product. Since the late time gravitino decays produce non-thermalized LSPs, the number density of gravitinos must be sufficiently small not to overproduce the non-thermalized LSPs.

Such a problematic gravitino particle presents some implications for high energy physics, since they are produced through various channels in supersymmetric inflation models. The production channels are as follows:

- ***Thermal scattering***

The gravitinos couple to MSSM particles and the radiation including the MSSM particles dominated our universe after the reheating. From scatterings of these MSSM particles, gravitinos can be overproduced, even if the gravitinos are not in thermal bath. Since the yield is proportional to the reheating temperature, it gives an upper bound on the reheating temperature.

- ***Inflaton decay***

It is revealed that the gravitinos are produced from decays of any scalar fields including moduli and inflaton field. Especially, gravitinos from the inflaton decay give severe constraints, since the energy density of inflaton is so tremendous to dominate the early universe. For this gravitino production process, inflation models are subject to severe constraints depending on the gravitino mass.

- ***Decay of the SUSY breaking field***

The SUSY breaking field also decays into gravitinos. Although it seems not so important due to its small number density compared with the inflaton field, it is very problematic for its strong coupling with gravitinos. Since the initial number density of the SUSY breaking field depends on inflation models, the inflation models are again constrained by this decay process.

Detailed studies about those production processes reveal that most of the inflation models and the supersymmetric theories are not necessarily compatible. It is disastrous especially when the SUSY breaking is mediated by Planck suppressed operators.

Under these circumstances, we study inflation models in the supersymmetric theory on this thesis. Especially, we focus on finding successful inflation models for any gravitino mass, even incorporating recently discovered gravitino production processes. For this purpose, we first reveal which inflaton potentials are consistent with the observed CMB fluctuation $n_s < 1$. After the examination of the gravitino yield based on these inflation models, we show that the inflation models can be roughly classified into three categories shown in Fig.1.

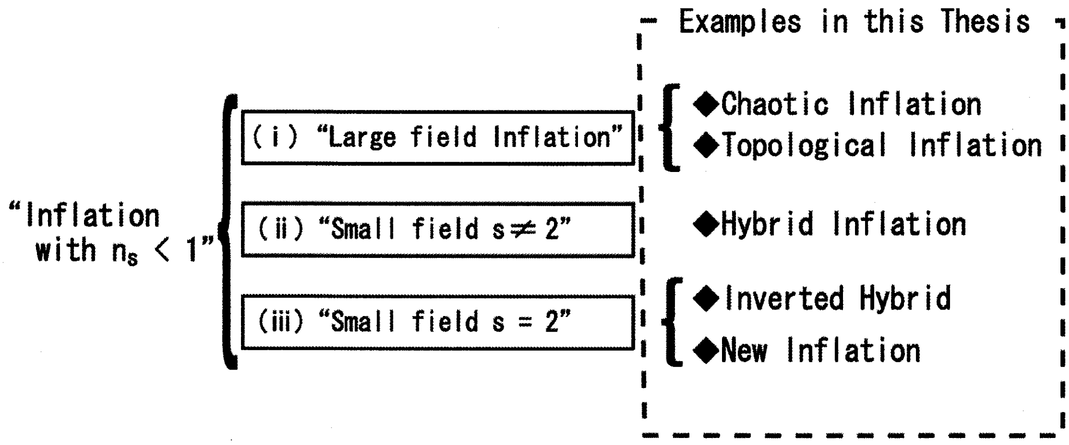

Fig.1 Inflation categories based on the gravitino production process and predictions for the CMB spectrum. Here "large" ("small") means a inflation models with field value larger (smaller) than the Planck scale and "*s*" is related to a curvature of the inflaton potential. See chapter 4 for more details of the definition.

We examine the gravitino production processes in each inflation categories and estimate the gravitino yield more accurately in some representative examples in Fig.1. As the result, we find that low scale inflation models with a specific curvature in the inflationary era, that is a inflation category (iii) in Fig.1 are very favored in the gravity mediation scenario and the gauge mediated SUSY breaking models are consistent with most of the inflation models. More detailed relation between the inflation models and mediation scenarios are well summarized in the conclusion of this thesis.