D-term SUSY Breaking Might Solve
The Moduli/Inflaton-Induced Gravitino Problem

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ABSTRACT & SUMMARY

We reconsider the moduli/inflaton-induced gravitino problem in the presence of D-term supersymmetry (SUSY) breaking. Explicit expressions of the effective coupling constant for modulus/inflaton decay to a pair of gravitinos are obtained. The problem could be solved if some parameters of a model are suppressed although suppression of gravitino production is not a generic consequence of D-term SUSY breaking.

The Moduli/Inflaton-induced Gravitino Problem

Supergravity (SUGRA) and superstring/M-theory contain long-lived particles such as gravitino, dilaton, and moduli. These long-lived particles, if produced amply, may make a contradiction between cosmological observations and theoretical prediction (the cosmological moduli problem [1,2] and the gravitino problem [3]). There are cosmological bounds on masses of these particles, the reheating temperature of the universe, and so on (Fig. 1). Things are more complicated and the problems are related. The branching ratio of modulus decay into gravitinos significantly affects the decay rate significantly [9]. Moreover, heavy scalars (e.g. inflatons) can decay into gravitinos too [7,8]. This is the moduli/inflaton-induced gravitino problem.

W/o D-term (Known Facts)

Important decay channel
Gravitino pair production is the main decay channel.

Lagrangian & the partial decay rate
The relevant part of Lagrangian density and the partial decay rate are given below [5,6].

\[ L = - \frac{i}{8} e^{\mu \nu \lambda \sigma} \left( G_\sigma \partial_\mu \phi - G_\phi \partial_\mu \phi \right) \psi_\mu \gamma_\nu \psi_\sigma + \frac{1}{4} m_3/2 (G_\sigma \phi + G_\phi \phi) \partial_\mu \gamma^\mu \psi_i \]

\[ \Gamma = \frac{m_5^2 |G_\phi|^2}{288 \pi m_3^2 m_2^2} \left( G_\phi \right)^2 \left( G_\phi \right)^2 \]

Mixing & an effective coupling constant
Mixing between moduli/inflaton “ϕ” and the SUSY breaking field “z” affects the decay rate significantly [9]. It is useful to define an effective coupling constant [10] to express the decay rate from the mass eigenstate moduli/inflaton “״” into two gravitinos.

\[ \Gamma = \frac{m_5^2 |G_\phi|^2}{288 \pi m_3^2 m_2^2} \left( G_\phi \right)^2 \left( G_\phi \right)^2 \]

W/ D-term (Our Results)

Differences from “only F-term”
The important (nontrivial) channel and the corresponding Lagrangian density do not change. Moreover, the definition of the effective coupling constant is the same as eq. 1.

On the other hand, explicit formulae of the vacuum conditions become more complicated, and mass formulae change, so does the amount of mixing between modulus/inflaton “ϕ” and the SUSY breaking field “z”.

Straightforward evaluation reveals [4,11] the dominant contributions to the effective coupling constant. The following eq. is the generalization of eq. 1.

\[ |G_\phi|^2 = \frac{1}{8} \left( \frac{m_5^2}{m_3^2} \right)^2 \left( m_3 \right)^2 \left( m_5 \right)^2 \left( m_2 \right)^2 \left( G_\phi \right)^2 \left( G_\phi \right)^2 \]

where \( m_X = \max \{ m_\phi, m_2 \} \), and

\[ |G_\phi|^2 = \frac{1}{8} \left( \frac{m_5^2}{m_3^2} \right)^2 \left( m_3 \right)^2 \left( m_5 \right)^2 \left( m_2 \right)^2 \left( G_\phi \right)^2 \left( G_\phi \right)^2 \]

References