Moduli Stabilization and Moduli-Induced Gravitino Problem

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What is Moduli?

Scalar Fields in SUGRA/Superstring

- Flat direction —— almost massless

  Mass is given by stabilization
  and related to ~~SUSY~~/Non-Perturb.

  $$\longrightarrow \quad m_\phi \sim m_{\rm soft}$$

- Weak Interaction —— Planck suppressed

  Decay rate : $\Gamma_X = \frac{c}{4\pi}\frac{m_\phi^3}{M_P^2}$

Cosmological Moduli Problem

[Coughlan,Fischler,Kolb,Raby&Ross;Banks,Kaplan&Nelson;
Carlos,Casas,Quevedo&Roulet]

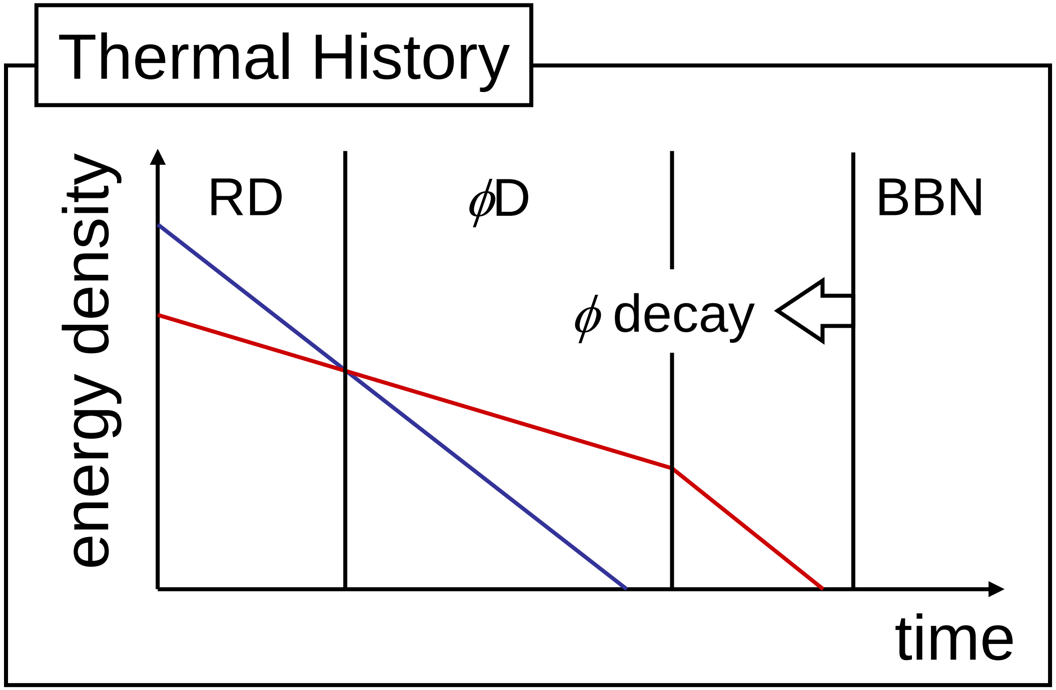
Problem of Light and Long-Lived Scalar Field

- develop a large VEV during inflationary period and dominate energy of universe

- decay can upset success of BBN very easily

- constraint on τ_ϕ

  $\tau_\phi < O(0.1)$ sec



… Many Solutions Proposed

- **Heavy Moduli Scenario** [Ellis,Nanopoulos&Quiros]

  … depends on moduli stabilization

- Enhanced Symmetry Points [Dine,Nir&Shadmi]
- Large Hubble-Induced Mass [Linde]
- Weak scale inflation [Randall&Thomas;Lyth&Stewart]
- Domain wall [Kawasaki&Takahashi]

and more…

Heavy Moduli Scenario : $m_\phi \gtrsim 100$ TeV

Mass is determined by moduli stabilization

- Gaugino condensation (e.g. KKLT)

$$m_\phi \sim O(10) \times m_{3/2}$$

- Racetrack

$$m_\phi \sim O(10^2) \times m_{3/2}$$

cf. Gravitino mass is bounded from above

$$m_{3/2} \lesssim 100 \text{ TeV}$$

Heavy Moduli Scenario : $m_\phi \gtrsim 100$ TeV

mass is determined by moduli stabilization

Modulus decay is NOT protected by symmetry

- Gau…)

$$m_\phi \sim O(10) \times m_{3/2}$$

- Racetrack

Moduli-Induced Gravitino Problem

cf. Gravitino mass is bounded from above

$$m_{3/2} \lesssim 100 \text{ TeV}$$

Branching Ratios of Moduli Decay

Radiations e.g. dilatonic coupling, $\frac{\lambda_G}{M_P}\int d^2\theta\,\phi WW$

$$\Gamma(\text{gauge boson}) \simeq \Gamma(\text{gaugino}) \simeq \frac{3|\lambda_G|^2}{2\pi}\frac{m_\phi^3}{M_P^2},$$

Gravitino Production

$$\Gamma(\phi \to 2\psi_{3/2}) \simeq \frac{|\kappa|^2}{288\pi}\frac{m_\phi^3}{M_P^2},$$

$$B_{3/2} \sim B_{\text{LSP}} \sim B_{\text{rad}}$$

indep. of m_ϕ

$\kappa = O(1)$

[ME,Takahashi&Hamaguchi;Nakamura&Yamaguchi]

[cf. Brignole,Casas,Espinosa&Navarro]

Gravitino Production Rate : $B_{3/2} \sim |\kappa|^2$

Generically $\kappa = O(1)$ at vac. in mass-eigenstate basis,
where *z* is SUSY breaking field

- Kaehler mixing : $K \sim \kappa \phi^\dagger z z + h.c.$

  ϕ and *z* are not protected by sym. at vac.

- mass of SUSY breaking field (e.g. DSB)

  $$m_Z > m_\phi \quad \longrightarrow \quad \kappa \sim \nabla_\phi G_z \sim O(1)$$

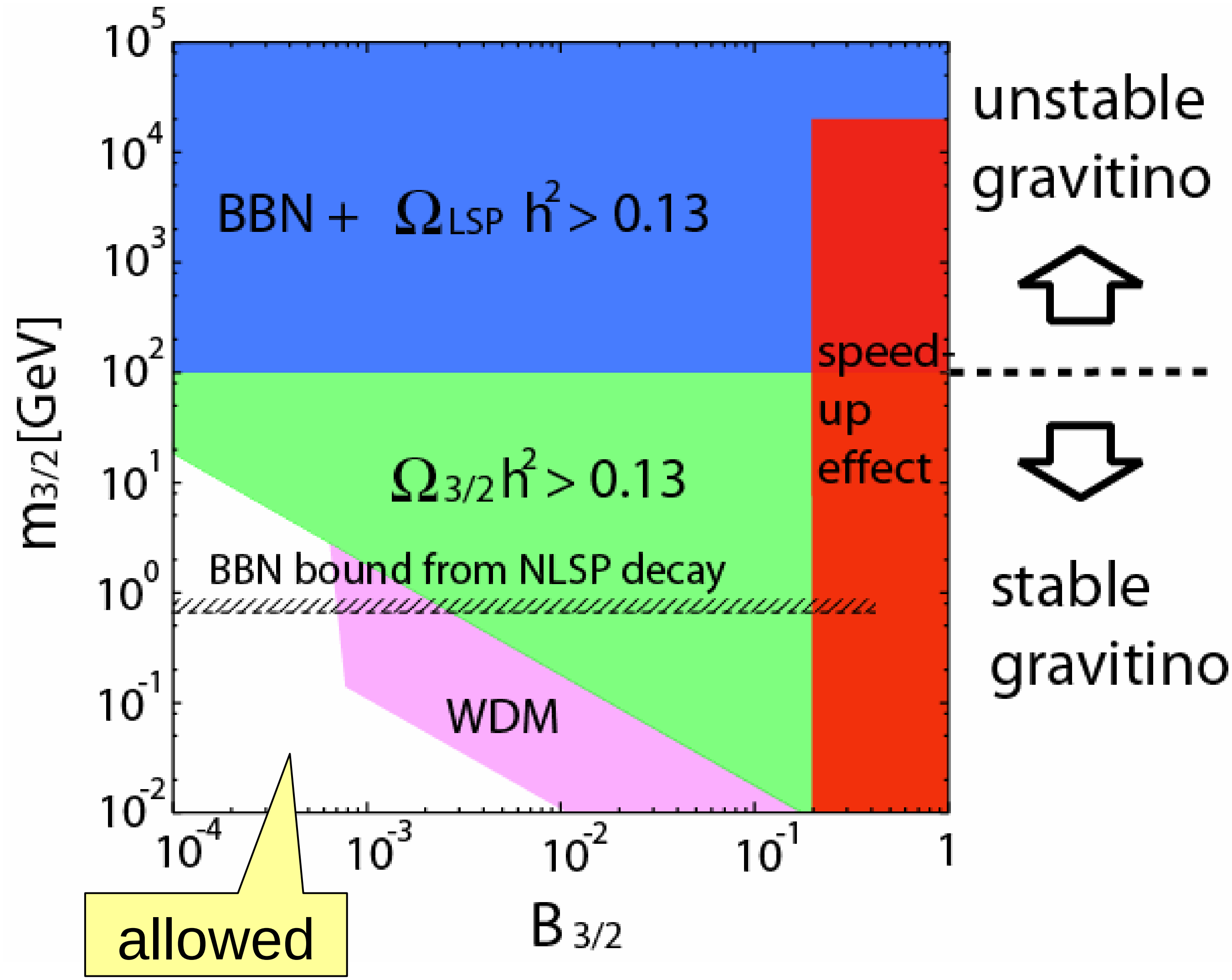
cf. (accidentally) minimal Kaehler & $m_Z < m_\phi$

$$\kappa \sim m_{3/2}/m_\phi < O(1)$$

[Dine,Kitano,Morrise&Shirman;ME,Takahashi&Hamaguchi]

Cosmological Bounds

$m_\phi = 10^3$ TeV



[ME,Takahashi&Hamaguchi]

Cosmological Bounds

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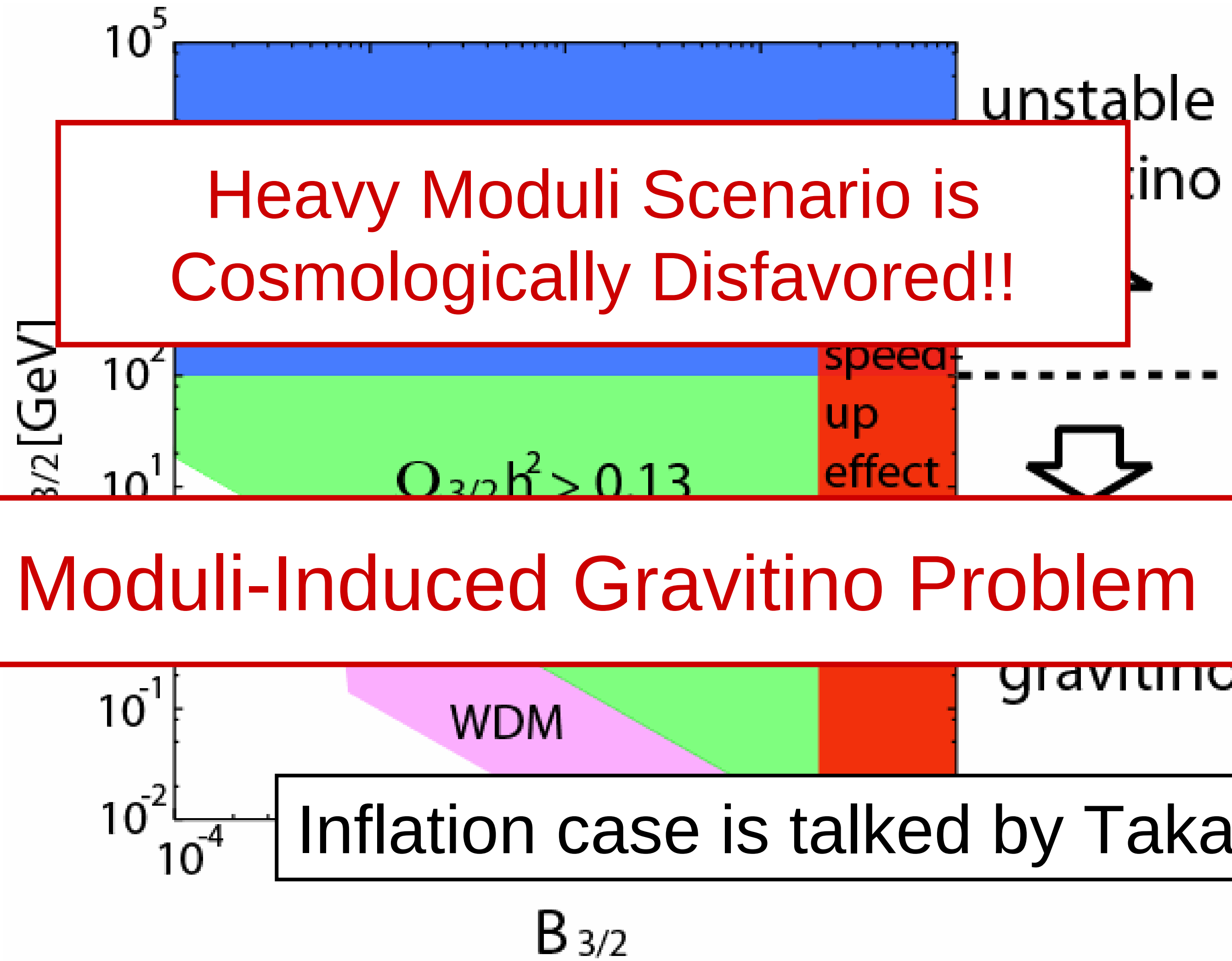

Heavy Moduli Scenario is Cosmologically Disfavored!!

Moduli-Induced Gravitino Problem

Inflation case is talked by Takahashi

[ME,Takahashi&Hamaguchi]

Possible Solutions of MIG Problem

○ dilution e.g. thermal inf., Q-ball, …

the field should be free from MIG problem

○ heavy Gravitino : $m_{3/2} \gtrsim 10^{3-4}$ TeV

~~SUSY~~ med. by superconformal anomaly

○ super-heavy moduli

supersymmetric stabilization

○ suppress κ at vac.

symmetry-preserved stabilization mechanism

Summary

Heavy moduli field is generically plagued with the Moduli-Induced gravitino problem.

Solution:

moduli stabilization mechanism which preserves symmetry @ vac.,
/ we require subtleties for the other sector.