A Universe with scalars not afraid of high reheating temperatures

- *I.Dalianis and Z.Lalak,JHEP (2010) 045*
- *I.Dalianis and Z.Lalak, Phys. Lett. B (2011) 385*
- *in preperation*

Ioannis Dalianis

IFT UW

Scalars, 27/8/2011

Scalars:

1) ***Supersymmetry***: Symmetry that transforms fermionic states into bosonic and vice-versa. A (**broken**) theory that contains scalars

2) ***Superstring theories****:*

   - Closed string spectrum: The **dilaton** field

   - Compactification: The **moduli** fields

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The Universe was Reheated:

1) CMB, BBN the universe experienced a ***thermal phase***

2) Homogeneity, Isotropy, Thermal fluctuations of CMB --> *Inflation*

→ ***A universe with scalars was reheated to possibly high temperatures.***

Why to afraid of a thermal phase?

1) Supersymmetry must be broken → Hidden Sector

$$\langle X \rangle_{\text{superfield}} = \langle X \rangle + \theta^2 F$$

Supersymmetry Breaking in a **Metastable Vacuum** (e.g. ISS set-up)

In the Gauge Mediation Scenarios the presence of messengers often ***restore*** **supersymmetry**.

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2) Moduli/Dilaton Fields are stabilized at **local minimum** that is separated by a barrier from the **runaway** → decompactification, zero-coupling regime

→ Our *Zero –Temperature* universe is realized *in a* ***META-STABLE*** *state*

Heating our Present Universe…

Whether this "gedanken experiment" is safe is model dependent. We choose our favorite models and we test them.

A) Supersymmetry Breaking Scheme:

*** Gauge Mediation**

*** Universal soft masses → Ordinary mediation models**

*** Minimal and attractive models → O'Raifeartaigh like models**

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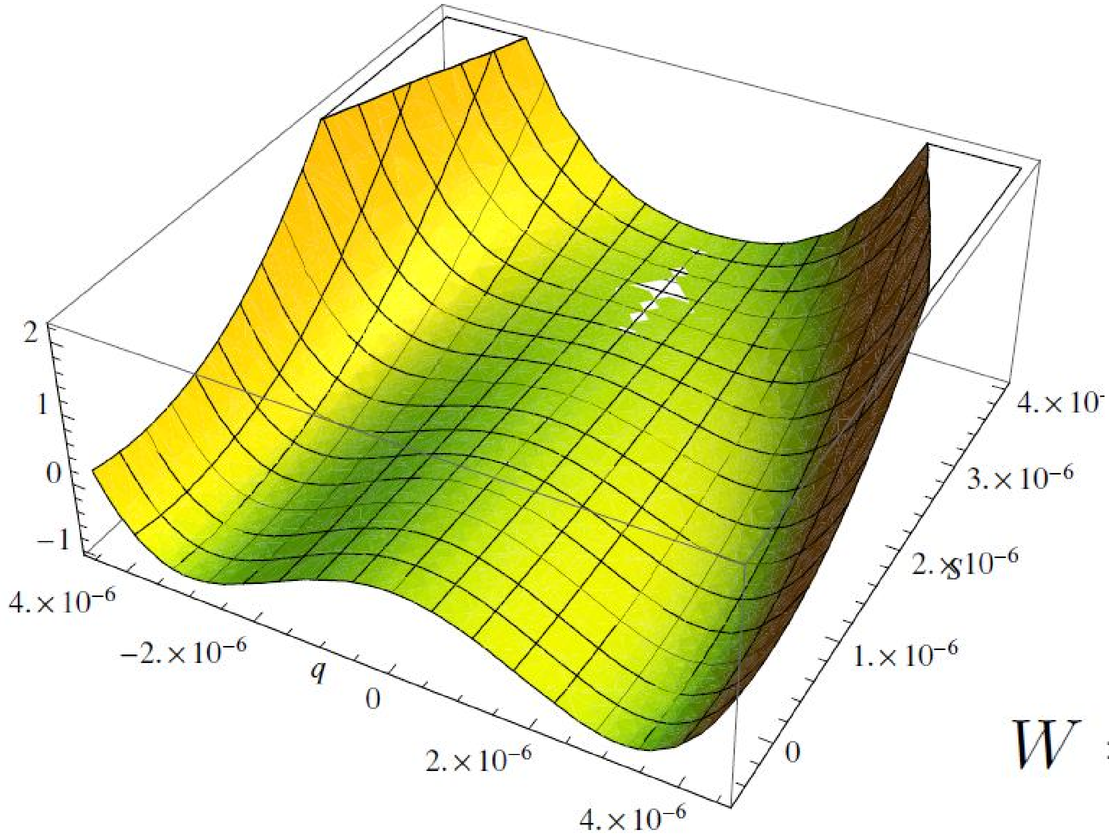
<u>Considering the supersymmetry breaking sector then:</u>

- N.J.Craig, P.J.Fox and J.G.Wacker, Phys Rev.D (2007)
- A.Katz, JHEP (2009) 054
- I.Dalianis and Z.Lalak,JHEP (2010) 045

} **Exact Supersymmetry**

A Metastable Example



$$W = FX - \lambda X \phi \bar{\phi} + c$$

$$K = X^{\dagger}X - \frac{(X^{\dagger}X)^2}{\Lambda^2}$$

I.Dalianis and Z.Lalak,JHEP (2010) 045

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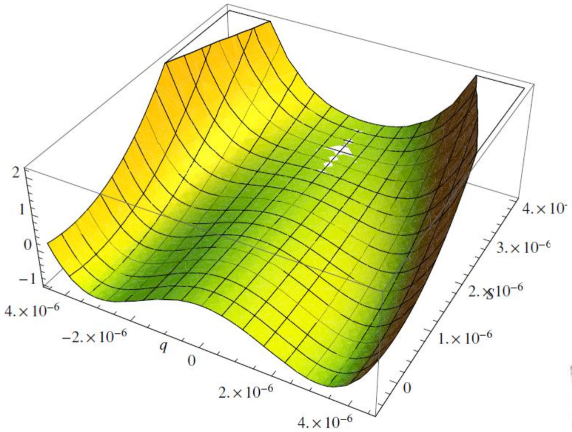
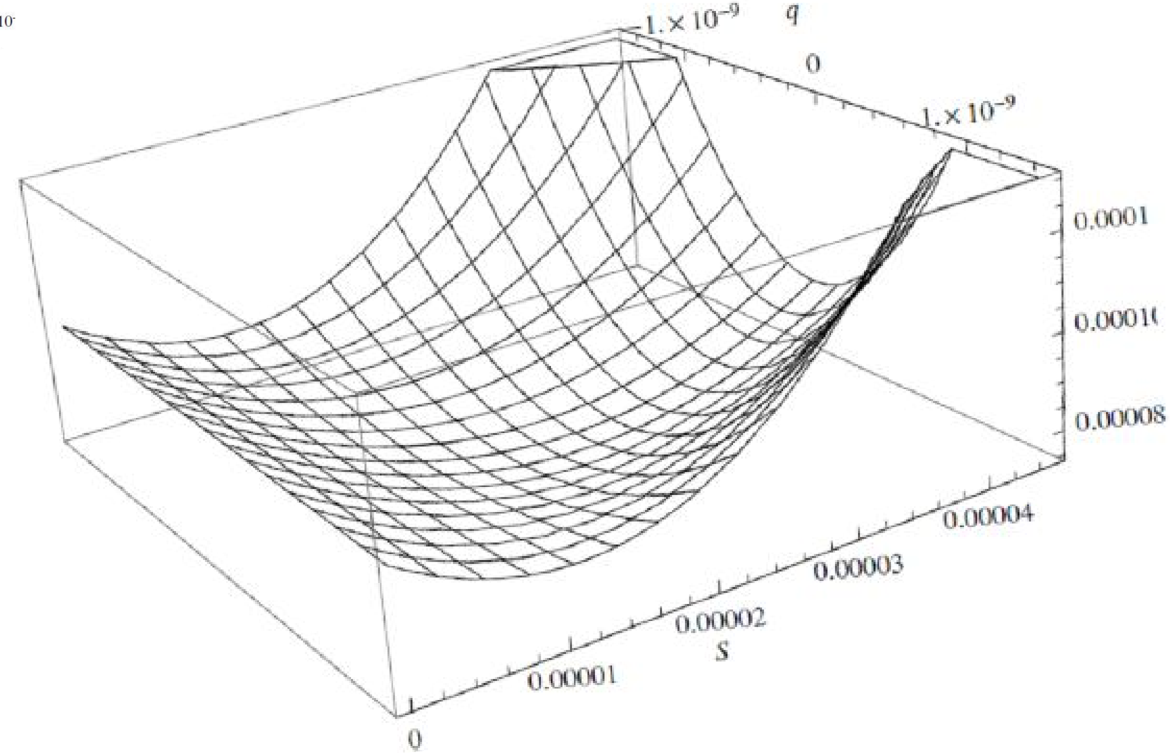


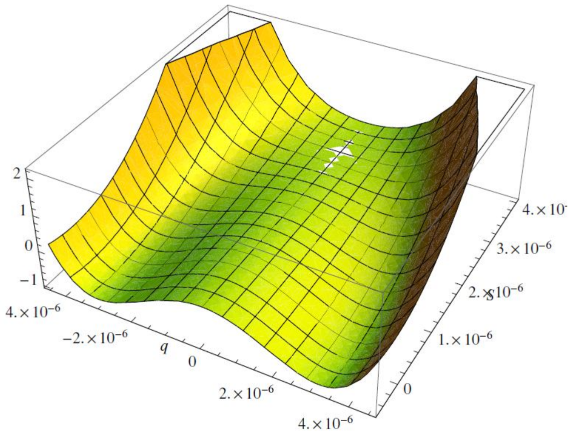


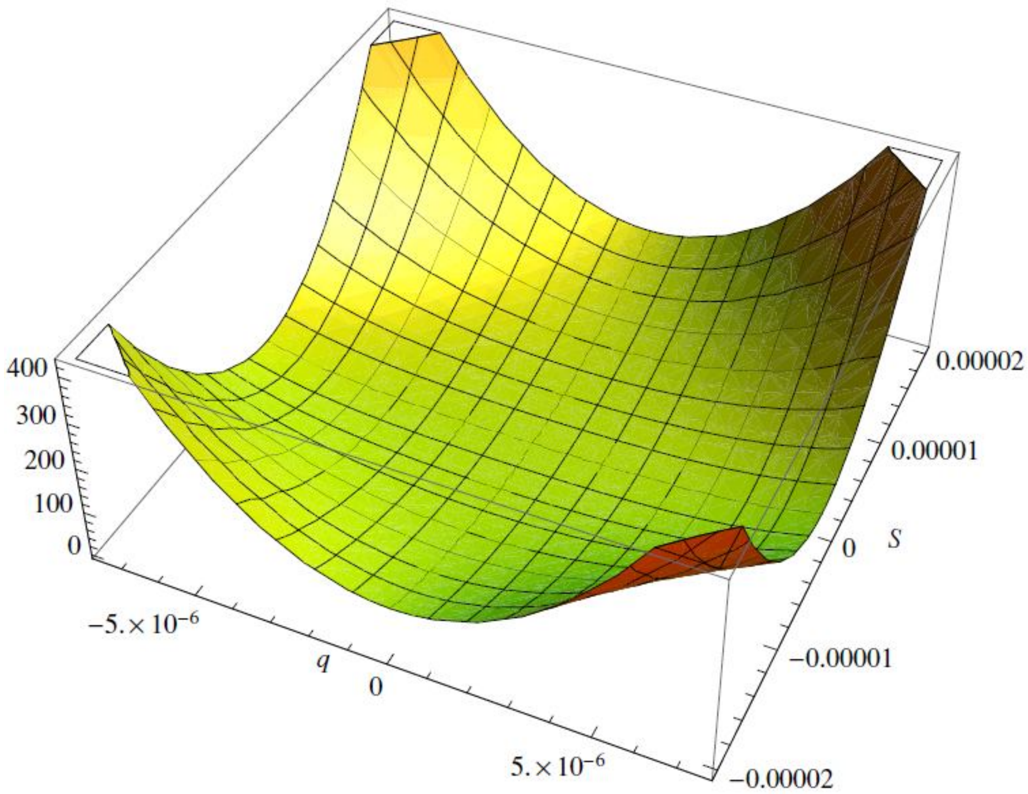
I.Dalianis and Z.Lalak,JHEP (2010) 045

Thermal Effects

The potential at finite temperature

The potential at T=0





I.Dalianis and Z.Lalak,JHEP (2010) 045

Thermally Favourable Gauge Mediation

I.Dalianis and Z.Lalak, Phys. Lett. B (2011) 385

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fire-sensitive

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3) **Kahler Correction & Global Susy & R-Symmetry Violating Mass Term**
   H.Murayama and Y.Nomura, Phys.Rev.D (2007) 095011

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3) **Kahler Correction & Global Susy & R-Symmetry Violating Mass Term**
H.Murayama and Y.Nomura, Phys.Rev.D (2007) 095011
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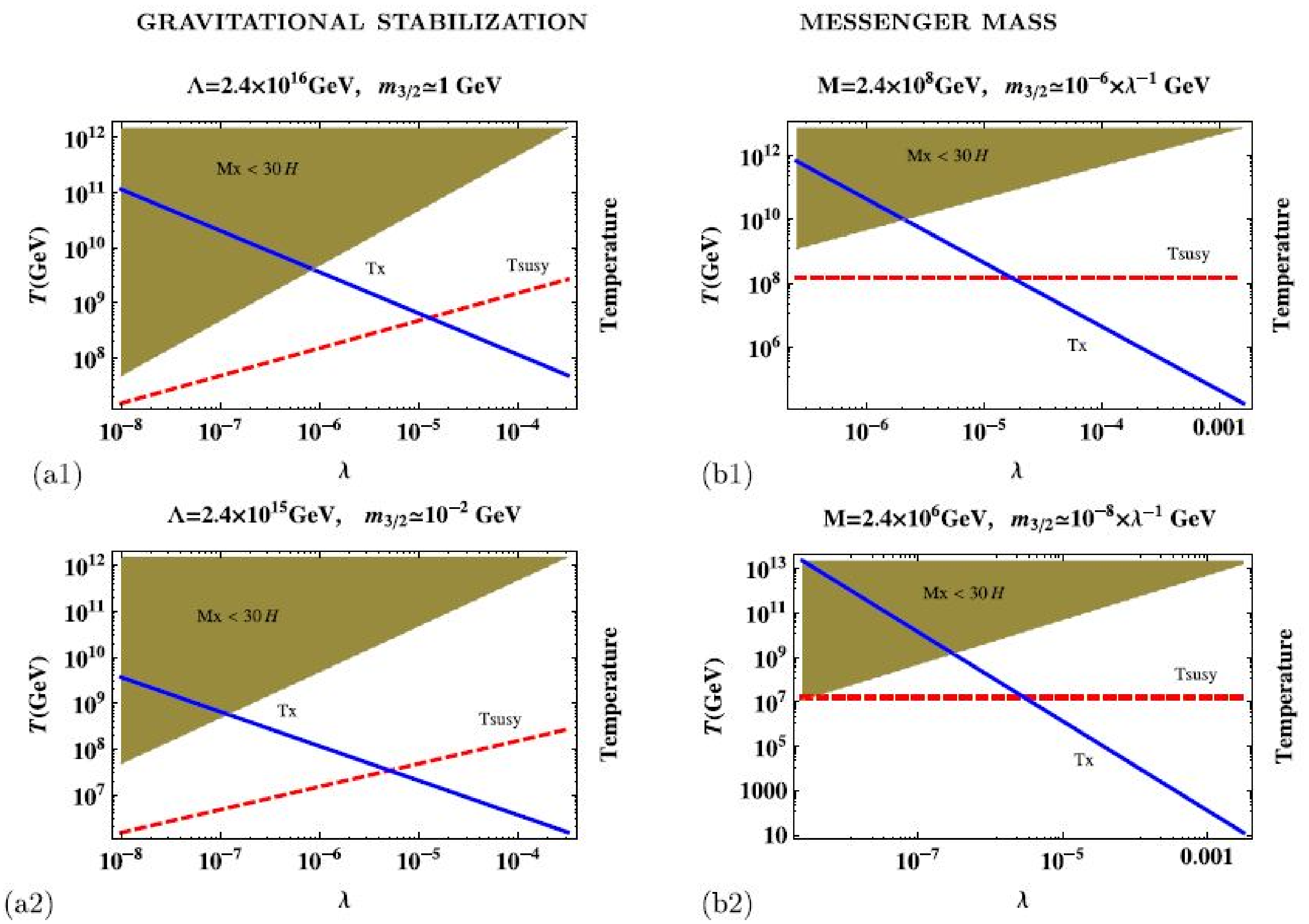
4) **Kahler Correction & Gravity, R-Symmetry Violation**
R.Kitano, Phys.Lett. B (2006) 203
fireproof

Thermally Favourable Gauge Mediation

I.Dalianis and Z.Lalak, Phys. Lett. B (2011) 385



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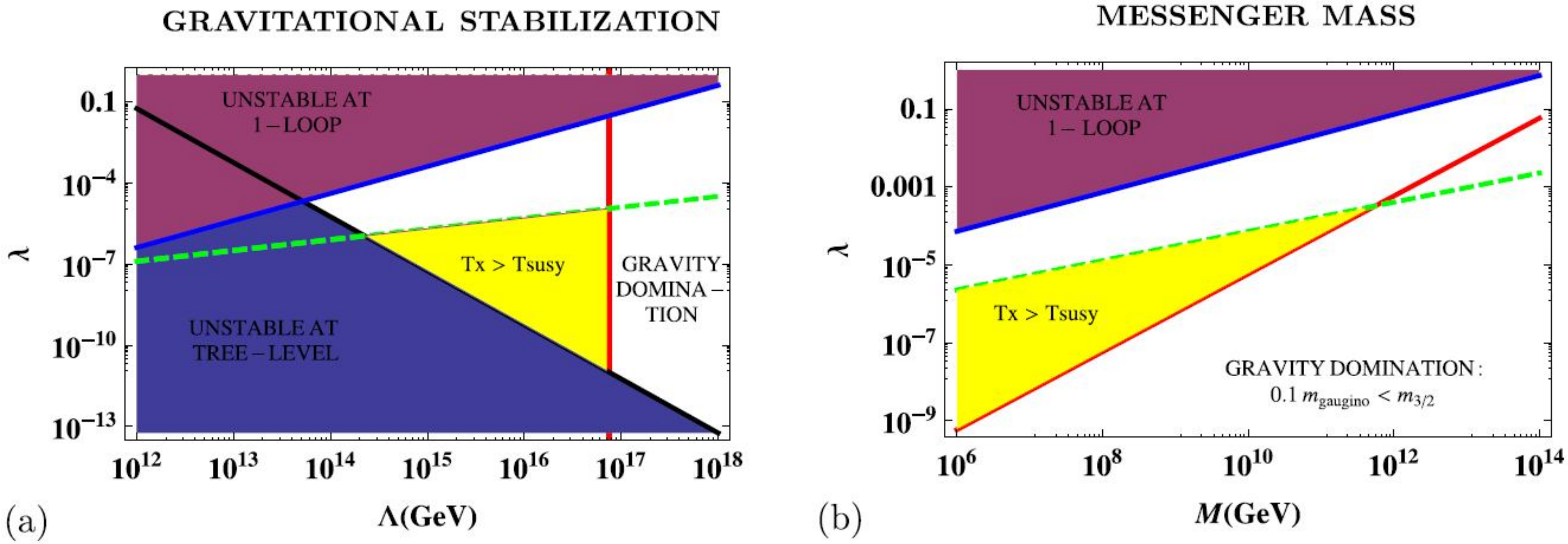

Features, phenomenology of ‘fireproof’ Gauge Mediation

- A coupling $$10^{-8} \lesssim \lambda < 10^{-4}$$

  can make the metastable vacuum thermally favourable

- The gravitino has mass $\mathcal{O}(10^{-3} - 1)$ GeV

- The spurion must be stabilized due to Kahler corrections. Hence, the GMSB hidden sector has a UV completion.

$$\Lambda^2 \sim m_0^2 / k_0^4$$

- The thermal selection is realized for *temperatures higher than*

$$\boxed{\mathcal{O}(10^7 – 10^9)} \quad \text{GeV}$$

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A) Supersymmetry Breaking Scheme

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A) Supersymmetry Breaking Scheme

B) Moduli Stabilization

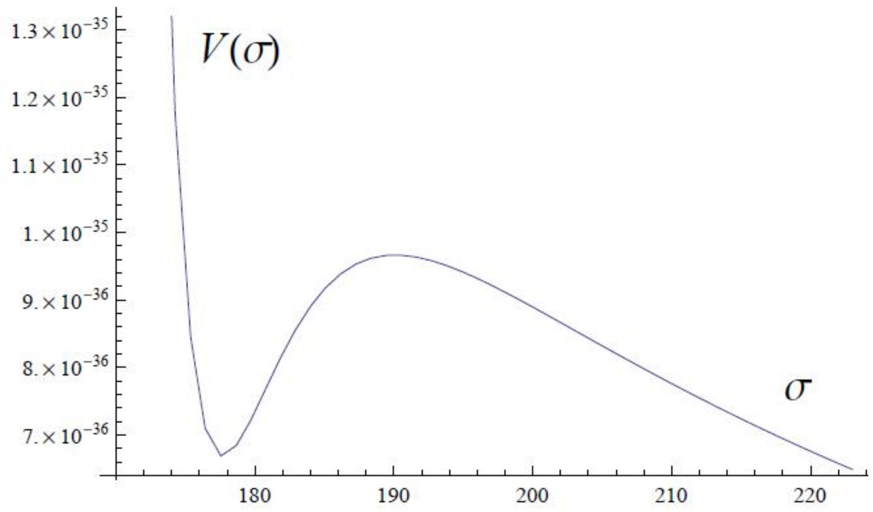
* **Dilaton & Complex structure Moduli stabilized at high scale**
R.Bousso and J.Polchinski, JHEP (2000) 006

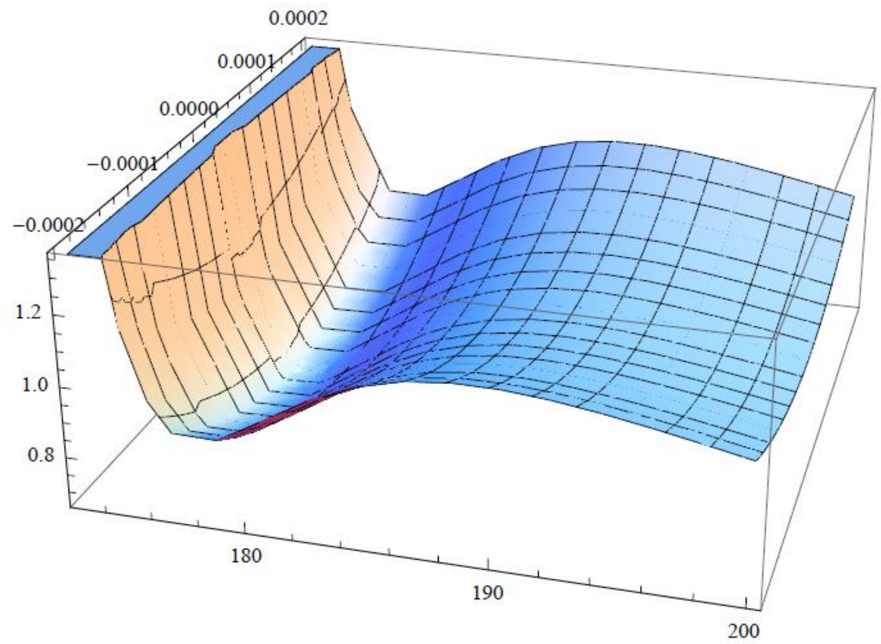
* **Volume Modulus stabilized e.g. according to the KKLT proposal**
S.Kachru, R.Kallosh, A.D.Linde and S.P.Trivedi, Phys.Rev. D (2003) 046005

* **The AdS vacuum uplifted by matter superpotentials that break Susy at low scale**

A Second Metastability

KKLT uplifted by Matter Superpotentials





A Second Metastability

- Although the moduli decoupled from the thermal plasma they control the value of the **gauge couplings**:

$$\sigma = \frac{4\pi}{g^2}$$

- **Free energy** of an SU(N) theory:

$$F(g,T) = -\frac{\pi^2 T^4}{24}\left\{\alpha_0 + \alpha_2 g^2 + \mathcal{O}(g^3)\right\}$$

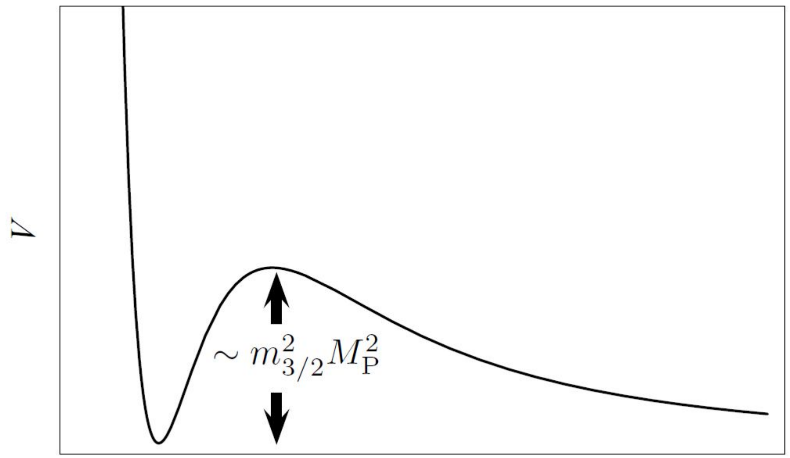
- There is a **critical temperature** where destabilization takes place:

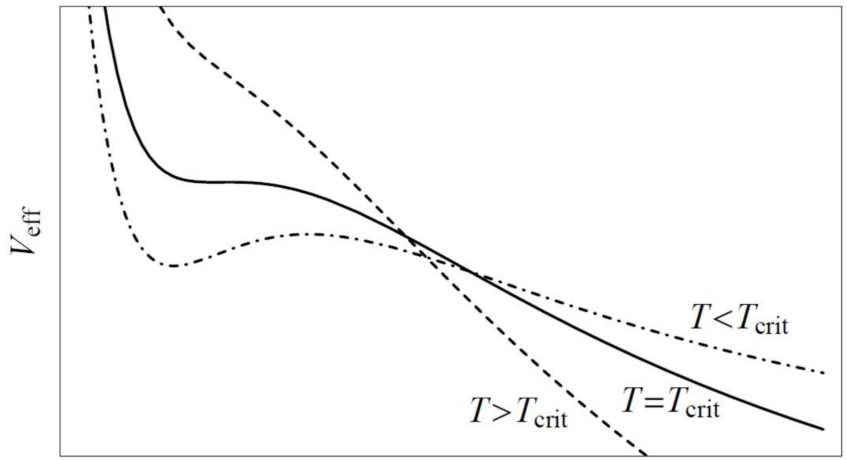
W.Buchmuller et.al Nucl. Phys. B (2004) 292

$$T_{\rm crit} \simeq c\sqrt{m_{3/2}}$$

Thermal destabilization

- *W.Buchmuller, K.Hamaguchi, O.Lebedev and M.Ratz, Nucl. Phys. B (2004) 292*
- *W.Buchmuller, K.Hamaguchi, O.Lebedev and M.Ratz, JCAP (2005) 004*





$$\text{for } m_{3/2} \sim 100 \text{ GeV} \rightarrow T_{crit} \sim 10^{10} \text{ GeV}$$

Kinematics

- ***Gauge mediation*** models cosmology more constrained *fire-sensitive*

- The modulus rolls over the barrier only when the curvature of the potential outweights the **Hubble friction**

- The mass of the modulus is given by the effective potential

$$V_{eff}(\sigma) = V(\sigma) - \frac{1}{3}\frac{r\rho_r g^2}{1 + rg^2}$$

- The "**runaway temperature**" is larger than the critical one.

less fire-sensitive

Conclusions

- There are minimal attractive models that although they yield **METASTABLE phenomenologically viable vacua** they are **thermally safe** or even preferred.

- If the **transition to the GLOBAL vacua** takes place during reheating then there is **no way back**

- Thermally disfavoured models cannot realize high temperature phenomena like thermal **leptogenesis** and are **dangerously unstable under thermal effects**.