THERMAL SELECTION OF PHENOMENOLOGICALLY VIABLE ~~SUSY~~ VACUA

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GAUGINO MASSES

- We consider general O'R models

$$\boxed{W = FX + (\lambda_{ij} X + m_{ij})\, q_i \bar{q}_i}$$

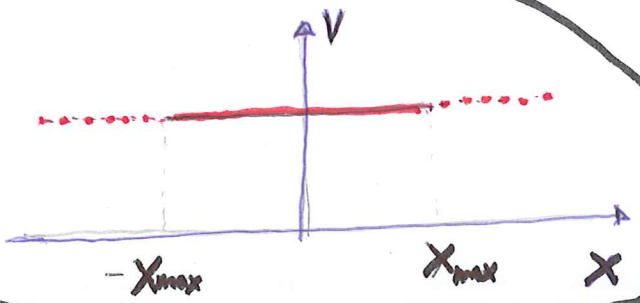
- Gaugino masses (Komargodski & Shih '09)

$$\boxed{m_\lambda \sim F^\dagger \frac{\partial}{\partial X} \log \det(\lambda X + m)}$$

TYPE I

- If $\det(\lambda X + m) = \det m$

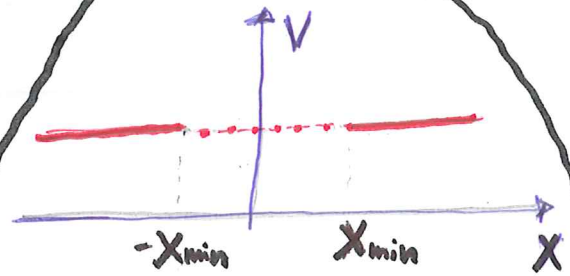
$\Rightarrow$ $\boxed{m_\lambda = 0}$



TYPE II

- If $\det(\lambda X + m) = X^N \det \lambda$

$\boxed{m_\lambda \sim m_{\tilde{q}}}$

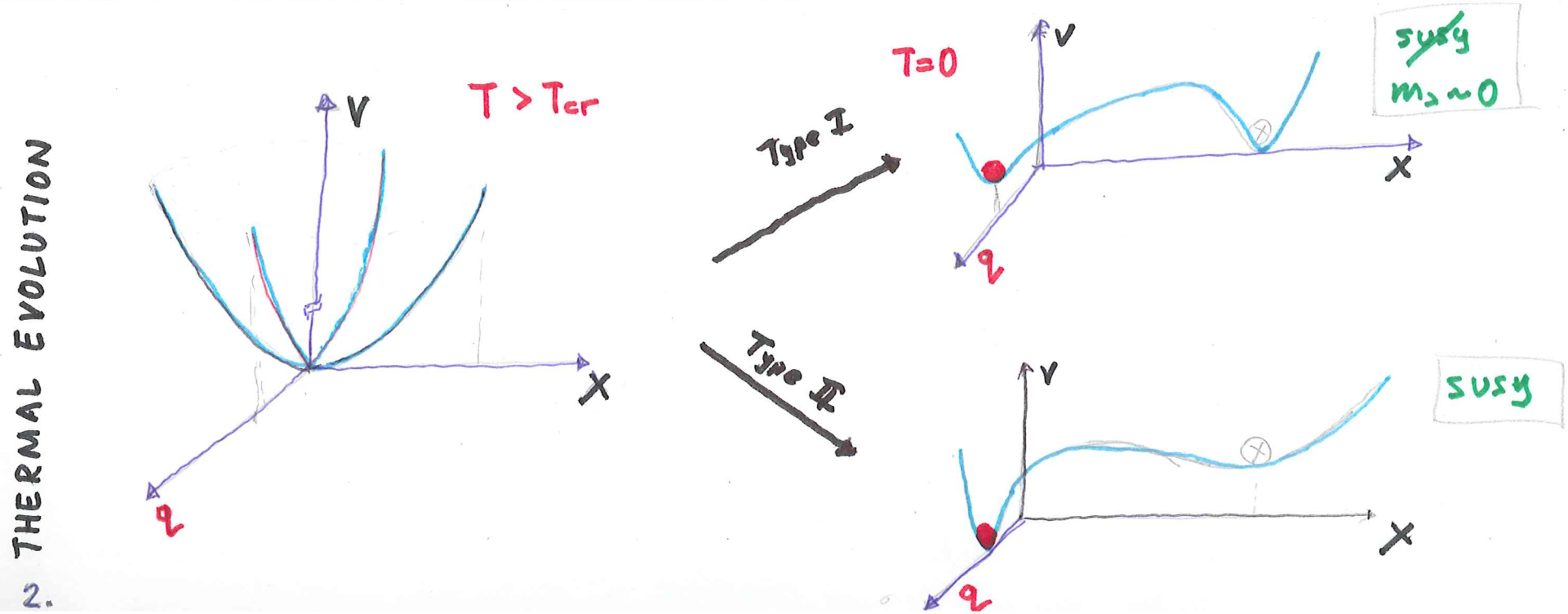


(Cheung et al '07)

THERMAL EVOLUTION (1)

- Type I ~~susy~~ vacua are thermally prefered
  Type II are thermally disfavoured
  (Abel et al, Craig et al, Fischler et al '06
  Katz '09, Dalianis & Lalak '10)

- To escape the problem: non-thermal evolution was considered



A WAY OUT

(Dalianis & Lalak '10)

- It is possible: SELECTION OF THE PHENO-VIABLE ~~SUSY~~ VACUUM DURING A THERMAL PHASE WITH HIGH T_{RH}

- If:

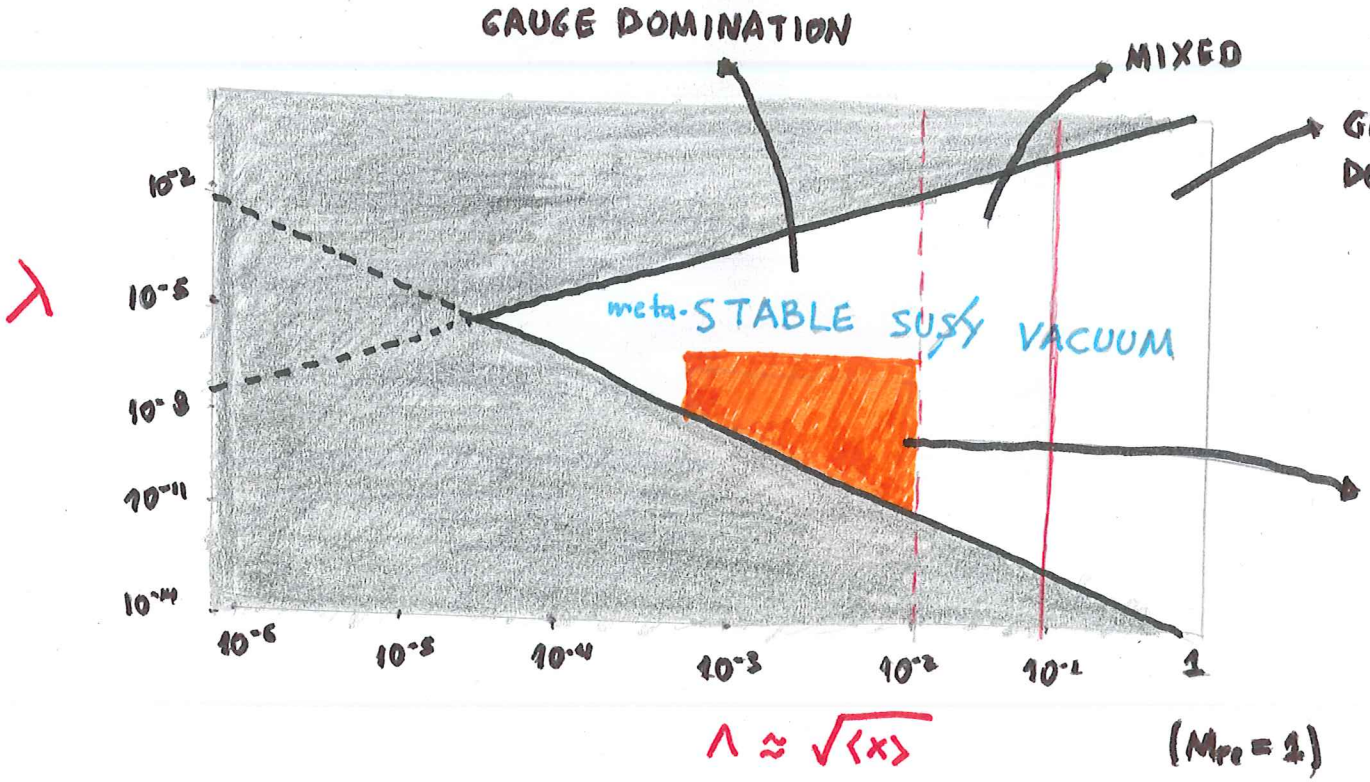
$$\left\{ \begin{array}{l} \boxed{X_{init} \neq 0} \\ \boxed{\lambda \text{ is small enough}} \end{array} \right. \longleftrightarrow \boxed{\text{INFLATION} \left\{ \begin{array}{l} W = W(I, X) \\ \delta K = -\dfrac{q^\dagger q \, I^\dagger I}{M_{Pl}^2} \end{array} \right.}$$

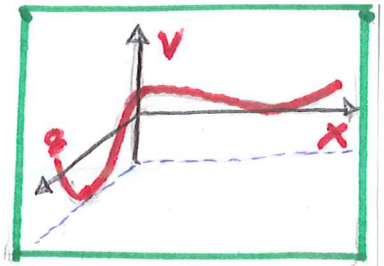
The Metastable Vacuum "emerges" at high Temperatures

$T_{RH} > M_{messengers}$ WANTED! DOES NOT RULE OUT ~~SUSY~~

X-THERMAL MASS VERY SMALL

(Dalianis & Lalak '10)





REALIZATION OF METASTABLE VACUUM WITH THERMALIZED MESSENGERS IS **POSSIBLE**

$(\langle x \rangle \quad , \quad \lambda)$	T_{RH} (GeV)
$(10^{14}\,\text{GeV} \quad 10^{-7})$	$10^{8.5} < T_{RH} < 10^{10}$
$(10^{14} \quad 10^{-8})$	$10^{8} < T_{RH}$
$(10^{12} \quad 10^{-7})$	$10^{7} < T_{RH} < 10^{9}$

COSMOLOGY

- ✓ Leptogenesis
- ✓ Thermal Dark Matter

(Olechowski et al '09)

$$\boxed{X_{initial} \neq 0}$$

→ DEPENDENCE ON INITIAL CONDITIONS

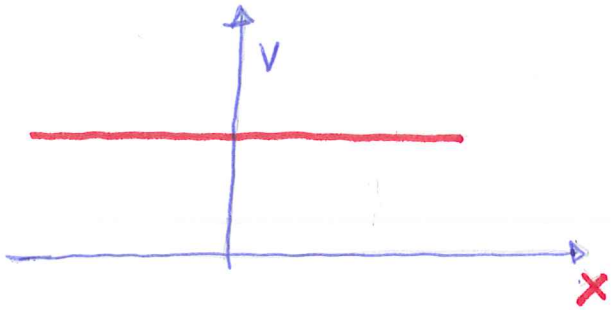
$$\boxed{\lambda \ll 1}$$

→ ANY OTHER CONSEQUENCES?

COUPLING λ + QUANTUM CORRECTIONS

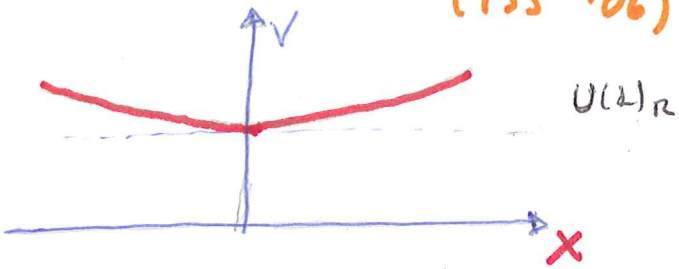
$$\boxed{\delta W = \lambda_{ij} X q_i \bar{q}_j}$$

1) It lifts the flat X-direction

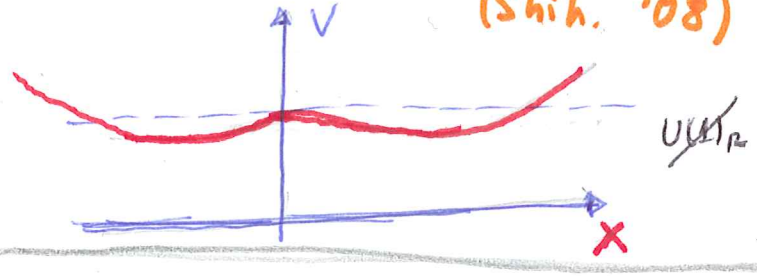


1-loop

(ISS '06)

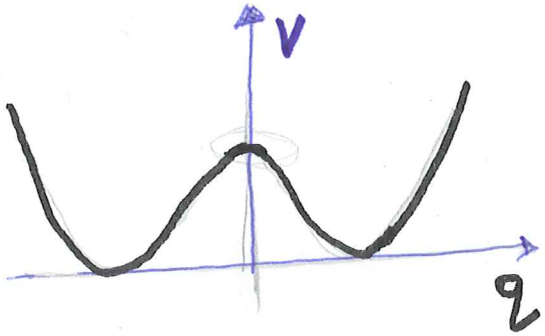


(Shih. '08)



2) In the q-direction?

$$W = FX - \lambda X q \bar{q}$$

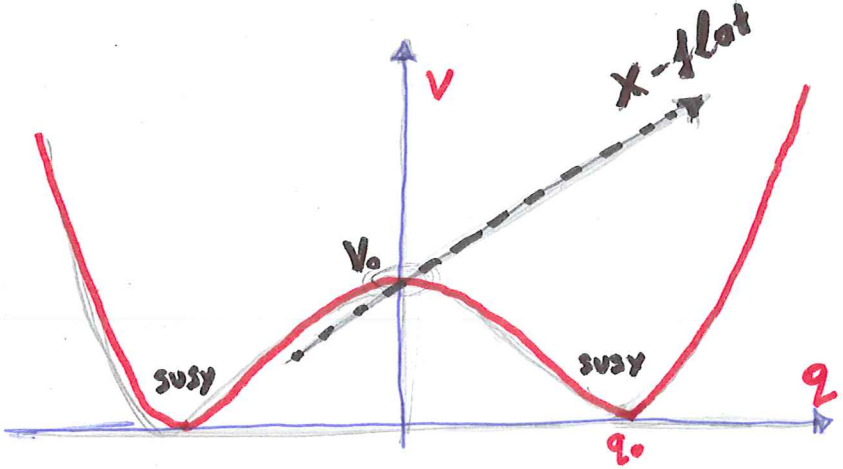


WHAT IF q IS CHARGED UNDER AN ABELIAN GAUGE GROUP $U(1)_q$ WITH CHARGE e ?

more on QUANTUM CORRECTIONS

- $$V^{1\text{-loop}} = \frac{1}{64\pi^2}\left(\mathrm{Tr}\, m_B^4 \log\frac{m_B^2}{\Lambda^2} - \mathrm{Tr}\, m_F^4 \log\frac{m_F^2}{\Lambda^2}\right)$$

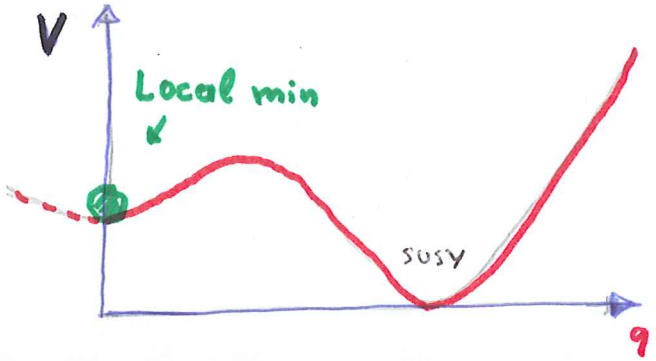
- WE ASSUME q CHARGED UNDER $U(1)_q$ (GAUGED)



$$\Rightarrow \boxed{V_{eff}^q = V_{0,R} + m_R^2 |\tilde{q}|^2 + \lambda_R^2 |\tilde{q}|^4 + (\alpha\lambda^4 + \beta e^4)|\tilde{q}|^4 \log\frac{|\tilde{q}|^2}{q_0^2}}$$

- $\lambda \ll 1 \Rightarrow \lambda/e \ll 1$

  and $m_R^2 > 0$



LINDE-WEINBERG LIMIT

GAUGED q - DIRECTION

HIGGSED

- It can generate **MASS HIERARCHIES IN SUSY THEORIES**

  $\langle x \rangle$ exponentially large (WITTEN '81)

- or NO-HIERARCHICALLY LARGE $\langle x \rangle$

  (ISS '07)

- IF GAUGE SYMMETRY NOT HIGGSED $\longrightarrow$ $\langle x \rangle = 0$

  $q = 0$

- R - SYMMETRY can be broken in various ways:

  NON-CANONICAL KÄHLER, GRAVITY, EXOTIC R-CHARGES

THERMAL EVOLUTION (2)

- THERE IS NO 2nd ORDER PHASE TRANSITION TO THE SUSY VACUUM $\left(\delta q_T < T/\sqrt{24} \right)$

- $X_{init} = 0$ is NOT problematic

- T_{RH} NOT constrained

IF λ/e SUFFICIENTLY SMALL

CONCLUSIONS

- There is NO THERMAL TRANSITION to SUSY Vacuum via tachyonic directions if $\lambda/e \ll 1$ and in a WINDOW of values

- GAUGINO MASSES ARE NOT VANISHING $(m_{\tilde{g}} \approx m_{\lambda})$

- But, λ CANNOT BE ARBITRARILY SMALL