SUPERSYMMETRY BREAKING FROM A GUT HIGGS

BORUT BAJC

(JSI, LJUBLJANA, SLOVENIA)

PLANCK 06

PARIS

WORK DONE WITH

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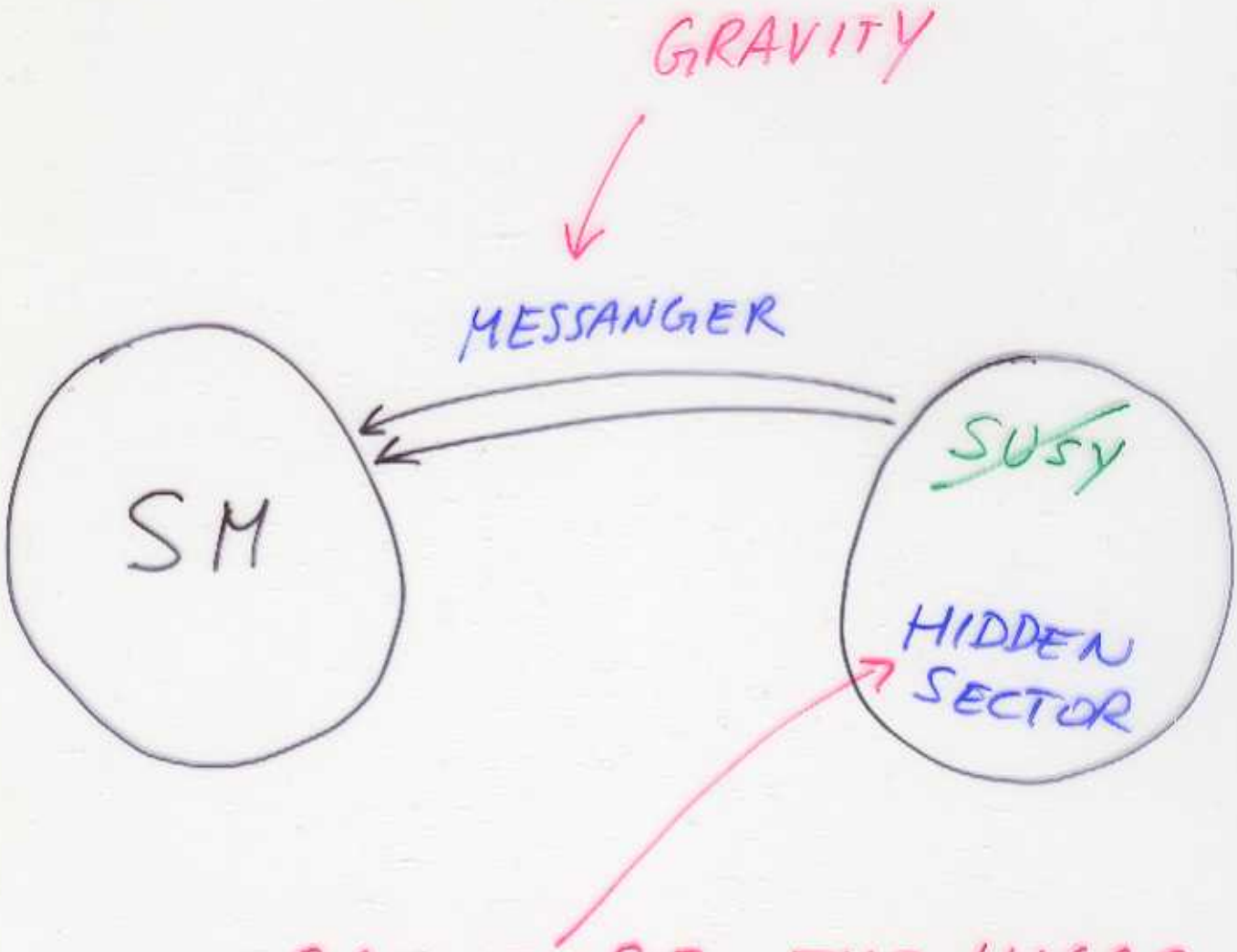

CAN IT BE THE HIGGS SECTOR IN A GUT ?

(FOR EX. 24_H IN SU(5))

RULES OF THE GAME :

(1) NO EXTRA INTERACTIONS EXCEPT GUT

(NO ROOM FOR DYNAMICAL SYMMETRY BREAKING OR FAYET-ILIOPOULOS)

AND GRAVITY

(= MESSANGER)

(2) NO SINGLETS

(NO ROOM FOR O'RAIFEARTAIGH)

CAN THE SAME FIELD BREAK BOTH GUT AND SCSV ?

TYPICALLY CONSIDERED DIFFICULT, DIFFERENT ARGUMENTS AGAINST IT

- ONE FIELD σ
- KÄHLER CANONICAL

$$V = e^{\frac{|\sigma|^2}{M_{Pe}^2}} \left(\left| W' + \sigma^* \frac{W}{M_{Pe}^2} \right|^2 - 3 \frac{|W|^2}{M_{Pe}^2} \right)$$

CONSTRAINTS ON $W(\sigma)$

$$\langle W \rangle = m_{3/2} M_{Pe}^2$$

$$\langle V \rangle = 0 \iff \langle W' \rangle = \sqrt{3}\, m_{3/2} M_{Pe} \left(1 + \mathcal{O}\left(\frac{\langle \sigma \rangle}{M_{Pe}} \right) \right)$$

$$\left\langle \frac{\partial V}{\partial \sigma} \right\rangle = 0 \iff \langle W'' \rangle = 2\, m_{3/2} \left(1 + \mathcal{O}\left(\frac{\langle \sigma \rangle}{M_{Pe}} \right) \right)$$

MINIMUM (NOT MAXIMUM) AT $\langle \sigma \rangle = M_{GUT}$ $\iff$ $$|\langle W''' \rangle| \leq \frac{2 m_{3/2}}{\sqrt{3} M_{Pe}} \left(1 + \mathcal{O}\left(\frac{\langle \sigma \rangle}{M_{Pe}} \right) \right)$$

WE NEED $W(\sigma)$ WITH THESE

4 CONSTRAINTS $\Rightarrow$ 4 FREE PARAMETERS

$$W = m\sigma^2 + \lambda\sigma^3 + \frac{c_1}{M_{Pe}}\sigma^4 + \frac{c_2}{M_{Pe}^2}\sigma^5$$

PARAMETRIZE

$$W = \frac{1}{M_{Pe}^2}\left(a_1 M_{GUT}^3\sigma^2 + a_2 M_{GUT}^2\sigma^3 + a_3 M_{GUT}\sigma^4 + a_4\sigma^5\right)$$

CLOSE TO $\sigma = M_{GUT}$ ALL 4 TERMS COMPARABLE

OVRUT, RABY, 83

DETERMINE a_1, a_2, a_3, a_4

TO GET THE MINIMUM OF V

AT $\tau = M_{GUT}$ WITH

$$\langle V \rangle = 0$$

$$\langle W \rangle = m_{3/2} M_{Pe}^2$$

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = M_{Pe}^2 \begin{pmatrix} 10 & -6 & \frac{3}{2} & -1/6 \\ -20 & 14 & -4 & 1/2 \\ 15 & -11 & 7/2 & -1/2 \\ -4 & 3 & -1 & 1/6 \end{pmatrix} \begin{pmatrix} \langle W \rangle / M_{GUT}^5 \\ \langle W' \rangle / M_{GUT}^4 \\ \langle W'' \rangle / M_{GUT}^3 \\ \langle W''' \rangle / M_{GUT}^2 \end{pmatrix}$$

NOTICE THAT THE SAME CONSTRAINTS MUST BE APPLIED TO CONVENTIONAL HIDDEN SECTORS (POLONYI-TYPE)

SMALL

$\longrightarrow$ SEVERAL PARAMETERS

$\longrightarrow$ VEV $= O(M_{Pe})$

BUT NO CANCELLATIONS NEEDED

SM SINGLET σ CAN COME FROM $\Sigma = 24_H$ IN SU(5)

$$W = m\,\mathrm{Tr}\Sigma^2 + \lambda\,\mathrm{Tr}\Sigma^3 + \frac{b_1^{(1)}}{M_{pe}}\mathrm{Tr}\Sigma^4 + \frac{b_1^{(2)}}{M_{pe}}(\mathrm{Tr}\Sigma^2)^2 + \frac{b_2^{(1)}}{M_{pe}^2}\mathrm{Tr}\Sigma^5 + \frac{b_2^{(2)}}{M_{pe}^2}(\mathrm{Tr}\Sigma^3)(\mathrm{Tr}\Sigma^2)$$

$$\Sigma = \sigma\begin{pmatrix} 2 & & & & \\ & 2 & & & \\ & & -3 & & \\ & & & -3 & \\ & & & & \end{pmatrix} + \begin{pmatrix} & & & & \\ & & & & \\ & & & & \\ & & & & \Sigma_3 \end{pmatrix}$$

$$a_i = f_i(m, \lambda, b_\alpha^{(\beta)})$$

4 PARAMETERS (DETERMINED!)

6 PARAMETERS (2 LEFT)

THIS FREEDOM ('TWO FREE PARAMETERS LEFT')

GOOD FOR THE SPECTRUM:

$$M_{3,8} \simeq \frac{M_{GUT}^3}{M_{PE}^2} \lesssim M_{GUT}$$

CAN BE DETERMINED FROM GAUGE COUPLING UNIFICATION CONSTRAINT.

A SOLUTION IS WELL KNOWN:

M_{GUT} ↑

$M_{TRIPLETS}$ ↑ ('30 X BIGGER')

$$\tau_p \simeq 10^3 \tau_p^0 \quad (M_{3,8} = M_{GUT})$$

WELCOME!

BAJC, FILEVIEZ PEREZ, SENJANOVIĆ, 02
BACHAS, FABRE, YANAGIDA, 95
CHKAREULI, GOGOLADZE, 98

PROBLEM

A GUT MULTIPLET Σ

TYPICALLY COUPLED TO SM FIELDS ϕ, $\bar{\phi}$

$$\int d^2\theta \, \Sigma \, \bar{\phi}\phi \Rightarrow F_\Sigma \bar{\phi}\phi = m_{3/2} M_{Pl} \bar{\phi}\phi$$

MASS TERM:

$$(\phi^*, \bar{\phi}) \begin{pmatrix} m_{3/2}^2 & m_{3/2} M_{Pl} \\ m_{3/2} M_{Pl} & m_{3/2}^2 \end{pmatrix} \begin{pmatrix} \phi \\ \bar{\phi}^* \end{pmatrix}$$

$\Rightarrow$ ONE NEGATIVE (AND LARGE) EIGENVALUE $\Rightarrow$ TACHYONIC STATE

UNLESS

MISSING PARTNER MECHANISM

THIS IS EXACTLY WHAT HAPPENS IN MINIMAL SU(5):

$$\bar{5}_H \left(\alpha 24_H + \mu \right) 5_H$$

$$24_H = \sigma \begin{pmatrix} 2 & 2 & 2 & & \\ & & & -3 & \\ & & & & -3 \end{pmatrix}$$

$$5_H = (T_5, D_5)$$

DOUBLETS LIGHT (MSSM HIGGSES)

$$\bar{5}_H = (\bar{T}_5, \bar{D}_5)$$

TRIPLETS HEAVY (MEDIATE PROTON DECAY)

DOUBLET-TRIPLET SPLITTING:

$$-3\alpha \langle \sigma \rangle + \mu = m_D \simeq 0$$
$$2\alpha \langle \sigma \rangle + \mu = m_T \simeq \sigma(M_{GUT})$$

$\Rightarrow$ CLEARLY $\alpha \neq 0$

$\Rightarrow \int d^2\theta \, \alpha \, 24_H \, \bar{5}_H \, 5_H$

$\Rightarrow \alpha \, F_\Sigma \, \bar{D}_5 \, D_5$ BAD!

MISSING PARTNER MECHANISM

MASIERO, NANOPOULOS, TAMVAKIS, YANAGIDA, 82

TRADE

$$24_H \longrightarrow 75_H$$

$$5_H \longrightarrow 5_H + 50_H$$

$$\bar{5}_H \longrightarrow \bar{5}_H + \overline{50}_H$$

DO NOT HAVE WEAK DOUBLETS

$$W = W(75_H) + M_{50}\,\overline{50}_H 50_H + 75_H\left(\overline{50}_H 5_H + 50_H \bar{5}_H\right)$$

BUT NO $\bar{5}_H 5_H$!

$$\longrightarrow (\bar{T}_5, \bar{T}_{50}) \begin{pmatrix} 0 & M_{GUT} \\ M_{GUT} & M_{50} \end{pmatrix} \begin{pmatrix} T_5 \\ T_{50} \end{pmatrix}$$

ALL TRIPLETS GET MASS

NO MASS FOR $D_5, D_{\bar{5}}$ $\Rightarrow$ MSSM HIGGSES LIGHT AND NOT COUPLED TO 75_H

CONCLUSIONS

(1) EXERCISE SUCCESSFUL :
BREAKING OF SUSY AND GUT
BY THE SAME FIELD POSSIBLE

(2) GUT + GRAVITY, NO SINGLETS
(GOOD NEWS)

(3) A LOT OF FINE-TUNING
(PRICE TO PAY)

(4) NOT MUCH INFORMATION ON
SOFT TERMS (AS IN POLONYI
IT DEPENDS ON KÄHLER)

(5) A LOT OF INFORMATION
ON THE HIGGS SECTOR

MOST IMPORTANT :
D=5 PROTON DECAY NATURALLY
PUSHED TO $\tau_p \to 10^{34}$ yrs