MINIMAL SUSY BREAKING IN GUTS

BORUT BAJC

(JSI, LJUBLJANA, SLOVENIA)

LHC DAYS
IN SPLIT 06

WORK DONE WITH

GORAN SENJANOVIĆ

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SUPERSYMMETRY (SUSY)

MOTIVATED BY (TALK SENJANOVIĆ!)

- GAUGE COUPLING UNIFICATION
- HIERARCHY PROBLEM
- DYNAMICAL ELECTROWEAK SYMMETRY BREAKING

SUSY PART OF MSSM (W) KNOWN (SUPER POTENTIA)

~~SUSY~~ PART OF MSSM UNKNOWN

PHENOMENOLOGICAL CONSTRAINTS:

DIRECT SEARCHES $\Rightarrow \tilde{M} \gtrsim 100\ \text{GeV}$

FCNC $\Rightarrow$ FLAVOUR STRUCTURE OF SFERMIONS SIMILAR TO ~~FERMIONS~~ (V_{CKM})

SUPERSYMMETRY:

$$e \longrightarrow E = \tilde{e} + \theta e + \theta\theta F$$

e — FERMION $S = 1/2$

E — SUPERFIELD

$\tilde{e}$ — BOSON $S = 0$

θe — FERMION $S = 1/2$

$\theta\theta F$ — AUXILIARY FIELD

θ ... GRASSMAN VARIABLE

$F \neq 0 \Longleftrightarrow$ ~~SUSY~~

① CAN WE BREAK SUSY IN MSSM ?

$F_{H,\bar{H}} \neq 0$ (THE ONLY POSSIBILITY)

$$\int d^2\theta\, y_e\, H_d\, L\, e^c \longrightarrow y_e F_H \tilde{e} \tilde{e}^c$$

$$V = \sum_i \left|\frac{\partial W}{\partial \varphi_i}\right|^2 = y_e^2 |H|^2 \left(|\tilde{e}|^2 + |\tilde{e}^c|^2\right) + \ldots$$

$$\left(\tilde{e}^*, \tilde{e}^c\right) \begin{pmatrix} y_e^2 v^2 & y_e^2 F \\ y_e^2 F & y_e^2 v^2 \end{pmatrix} \begin{pmatrix} \tilde{e} \\ \tilde{e}^{c*} \end{pmatrix}$$

$$m_{1,2}^2 = y_e^2 (v^2 \pm F)$$

$$\Downarrow$$

$$m_1^2 + m_2^2 = 2 m_e^2$$

IMPOSSIBLE!

SUCH

MASS SUM RULE

ALWAYS IN SUSY

AT TREE ORDER.

WAYS OUT:

a) USE OF LOCAL SUSY (SUGRA)

b) SUSY BREAKING BY LOOPS

IN BOTH CASES

NONRENORMALIZABLE OPERATORS

(BUT IN b) CALCULABLE)

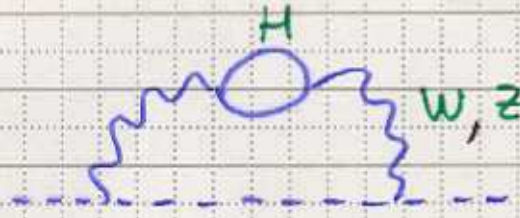
(2) CAN ONE ADD JUST ONE EXTRA FIELD X WITH $F \neq 0$? NO !

$\int d^2\theta \, H\bar{H}(\mu + X) \Rightarrow m_{\tilde{H}} = \mu$ (HIGGSINO)

$m_{H_1}^2 = \mu^2 - F$ (SM HIG

$m_{H_2}^2 = \mu^2 + F$

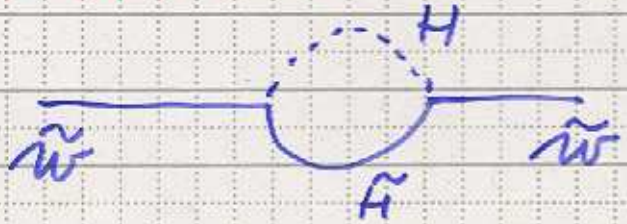
OTHER STERMIONS:



$\tilde{m}^2 \sim \left(\frac{\alpha}{4\pi}\right)^2 \left(\frac{F}{M}\right)^2 \ll F$

$F \sim \mu^2$ LARGE $(m_{H_1}^2 \sim m_W^2)$

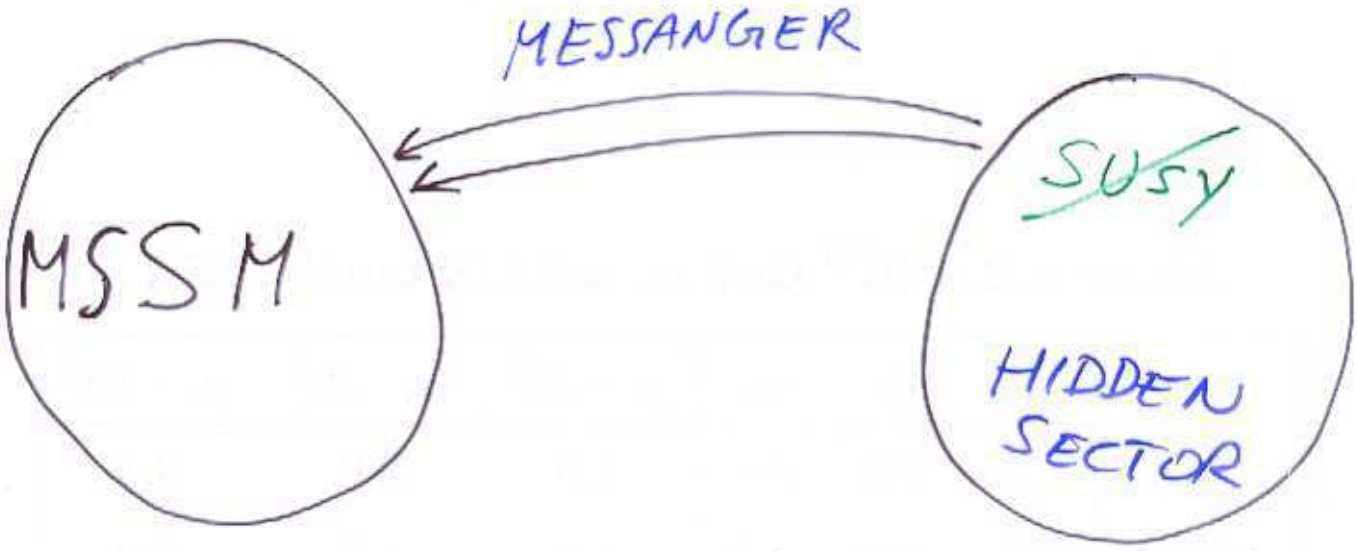
GAUGINO :



SIMILAR

BUT $y_t \sim 1$:

$\Rightarrow m_{\tilde{t}^c}^2 \simeq -y_t^2 F$ LARGE AND NEGATIVE


MESSANGER
MSSM
SUSY
HIDDEN
SECTOR

(3) FEW SHORT COMMENTS ON KNOWN MODELS OF SUSY :

(A) GRAVITY MEDIATION

MESSANGER ⟹ GRAVITY

– GRAVITY ALREADY THERE

– JUST A PARAMETRIZATION,
SOFT TERMS DEPEND ON
ASSUMPTIONS ON KÄHLER

CMSSM :

EVERYTHING CALCULABLE
IN TERMS OF FEW PARAMETERS
$(m_0, m_{1/2}, A, B, \dots)$,
BUT THEORETICALLY NOT MOTIVATED !

WHY SHOULD KÄHLER BE CANONICAL ?

(B) ANOMALY MEDIATION

AGAIN CONNECTED WITH GRAVITY, ALWAYS THERE

VERY PREDICTIVE ⇒ WRONG

$M^2 \sim \beta_g$ (RG INVARIANT)

⇒ SLEPTONS GET $M^2 < 0$

NEED TO COMBINE WITH OTHER SOURCES OF ~~SUSY~~ SUSY:

BACK TO OLD UNCERTAINTIES

(C) GAUGE MEDIATION

ALREADY SEEN AN UNSUCCESSFUL EXAMPLE WITH $-F_X \neq 0$

$-X$ COUPLED TO, $H\bar{H}$

$F_X \neq 0$ $\Longrightarrow$ MSSM

SM GAUGE BOSONS

EXTRA $q, \bar{q}, \ell, \bar{\ell}$

GETS ~~MSSM~~ MASSES

$$W = \lambda_q X \bar{q} q + \lambda_\ell X \bar{\ell} \ell + W_{MSSM}$$

APPARENTLY FLAVOUR CONSERVING

(GAUGE INTERACTIONS FLAVOUR BLIND)

BUT TO SAVE GAUGE COUPLING UNIFICATION

$5 \sim (q, \ell)$ $\qquad$ $\bar{5} \sim (\bar{q}, \bar{\ell})$

"d^c" $\qquad$ "L"

$\Rightarrow \tilde{Y} H \ell e^c$ POSSIBLE

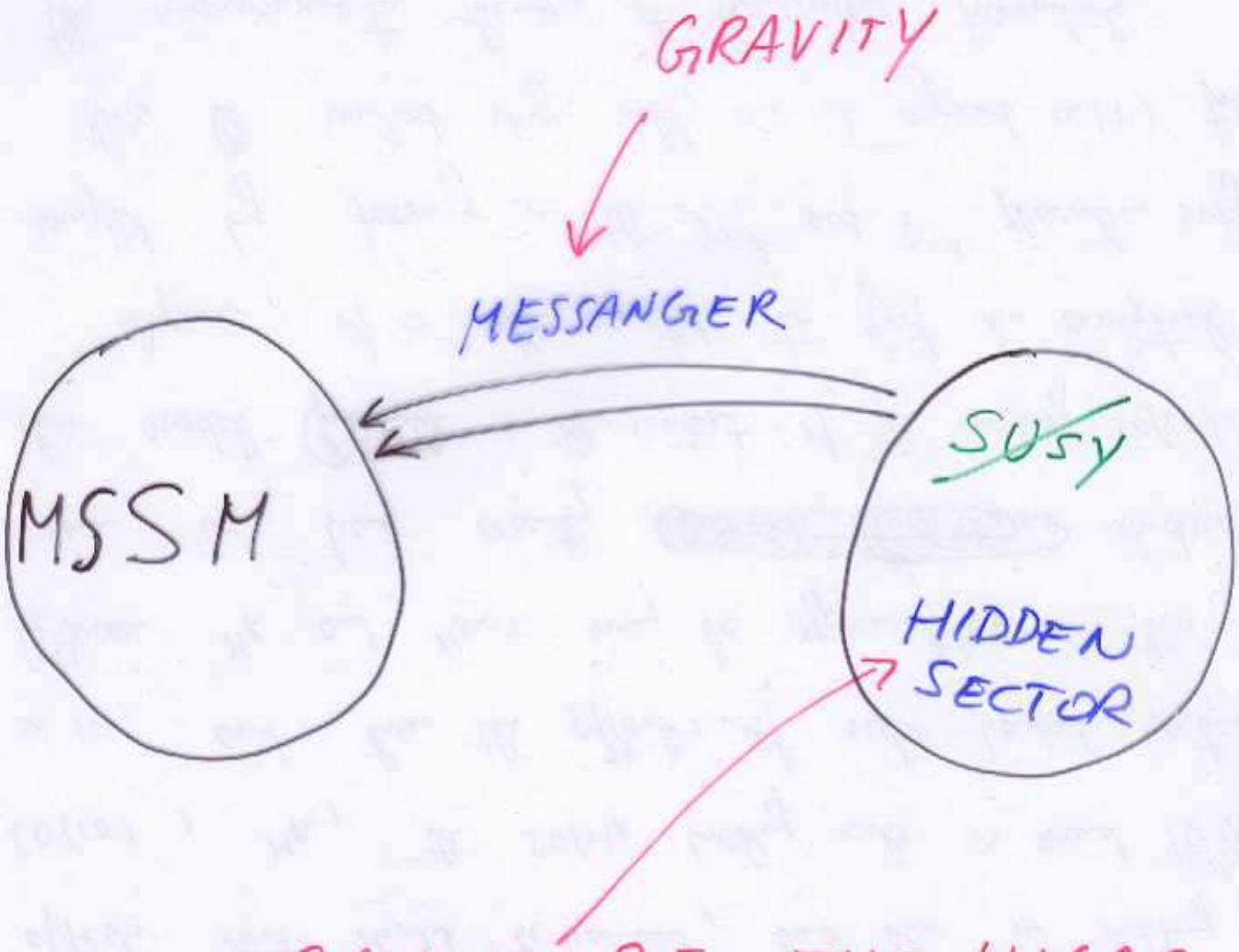
(EXTRA FLAVOUR MIXING!)

$\Rightarrow \tilde{Y} \ll 1$

NOT ~~MUCH~~ BETTER THAN SUGRA!

(4) SUSY NATURALLY TIED WITH GUTS (GAUGE COUPLING UNIFICATION)

CAN WE GET ANY INSIGHT IF WE CONNECT THE FIELD X THAT BREAKS SUSY ($F_x \neq 0$) WITH A GUT MULTIPLET ?



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)

$$\Sigma = \sigma \begin{pmatrix} 2 & & \\ & 2 & \\ & & -3 \end{pmatrix} + \left(\begin{array}{c|c} \Sigma_8 & \\ \hline & \Sigma_3 \end{array}\right)$$

SIMILAR TO X BEFORE

$$F_\sigma \neq 0$$

$$\langle \sigma \rangle = M_{GUT}$$

Σ_8 ... COLOR OCTET

Σ_3 ... WEAK TRIPLET

USUALLY $M_{3,8} \sim M_{GUT}$

(5) RESULTS

(A) CAN BE DONE, BUT FINE-TUNING NEEDED IN MINIMAL MODELS

$$\mathcal{O}(1) - \mathcal{O}(1) \simeq \mathcal{O}(10^{-13})$$

DUE TO

GAUGE COUPLING UNIFICATION CONSTRAINTS

(B) INTERMEDIATE MASS SCALES

$$M_{3,8} \sim \frac{M_{GUT}^2}{M_{PE}} \quad ; \quad \frac{\mu_3}{\mu_8} = 4$$

GOOD NEWS!

$$M_{GUT} = M_{GUT}^0 \left(\frac{M_{GUT}^0}{(\mu_3 \mu_8)^{1/2}} \right)^{1/2}$$

$$\mu_T = \mu_T^0 \left(\frac{\mu_3}{\mu_8} \right)^{5/2}$$

μ_T HEAVIER $\Rightarrow$ PROTON DECAY ($d=5$ SUPPRESSED

$$\tau_p \simeq 10^3 \tau_p^0$$

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