



New SUGRA-mediated NNMSSM-like structures

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L2C-Montpellier

NMSSM- ∞ workshop, Montpellier 6 March '18

Based partly on: arXiv:1611.10327 M. Rausch de Traubenberg, D. Tant, GM,
+ forthcoming collab: *S.low.SUGRA*, soutien projet IN2P3 (IPHC, L2C, LUPM, APC)



Where is –Is there– (TeV) New Physics ??

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- why is the Higgs so much SM-like??...(unitarity) why is it so light?
...(vanilla SUSY) why is it so heavy?
- is it elementary? ...is it composite?...
- No (direct) TNP experimental discovery so far, where contemporary paradigm expects it!
- seems to (seriously?) undermine the trust in the canons of TeV naturalness and fine-tuning.

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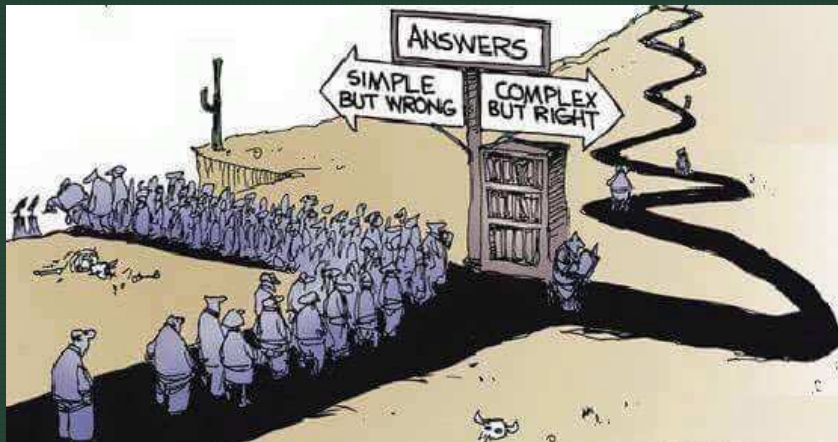
OR

...

3 → is the paradigm *totally* wrong?

could be a double-edged razor:





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→ deep connection between internal and space-time symmetries

→ unification with Gravity...

$N=1$ Supergravity potential

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with

$$\mathcal{D}_I W = W_I + \frac{1}{m_{pl}^2} K_I W$$

$$W_I \equiv \frac{\partial W}{\partial Z^I}, \quad K_I \equiv \frac{\partial K}{\partial Z^I}, \dots$$

$K^{IJ*} \equiv K_{IJ^*}^{-1}$, $K_{I^*J} = \frac{\partial^2 K}{\partial Z^{I^*} \partial Z^J}$ is the Kähler metric.

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$$\left(V_D = \frac{1}{2} (\text{Re } f)^{\alpha\beta}(Z) D_\alpha D_\beta \right)$$

F-term (local)SUSY breaking

$$\langle F^I \rangle \neq 0$$

$$F^I = e^{\frac{G}{2m_{pl}^2}} K^{IJ*} G_{J*}$$

$$G = K + m_{pl}^2 \log \frac{|W|^2}{m_{pl}^6}$$

$$m_{3/2} = \frac{1}{m_{pl}^2} \left\langle |W| e^{\frac{1}{2} \frac{K}{m_{pl}^2}} \right\rangle = m_{pl} \left\langle e^{\frac{1}{2} \frac{G}{m_{pl}^2}} \right\rangle ,$$

F-term (local)SUSY breaking

If SUSY breaking VEVs of hidden sector fields $\sim \mathcal{O}(m_{pl})$ then a strong consistency requirement:

all visible sector fields should not appear in the operators of the Lagrangian that diverge formally in the limit $m_{pl} \rightarrow \infty$.



Soni & Weldon *Phys. Lett. B*126, 215 (1983)

$$\begin{aligned} K(h, h^\dagger, \Phi, \Phi^\dagger) &= m_{pl}^2 K_2(z, z^\dagger) + m_{pl} K_1(z, z^\dagger) + K_0(z, z^\dagger, \Phi, \Phi^\dagger), \\ W(h, \Phi) &= m_{pl}^2 W_2(z) + m_{pl} W_1(z) + W_0(z, \Phi), \end{aligned}$$

where $h^i \equiv m_{pl} z^i$.

- ...It so happens that these forms always lead to SOFT susy breaking when mediated by gravity!
- → subsequent literature adopted these forms even though SUSY breaking VEVs are not necessarily $\mathcal{O}(m_{pl})$:

$$W(h, \Phi) \rightarrow m_{pl}^2 W_2(z) + W_0(\Phi),$$

⇒ Planck suppressed couplings between hidden and visible sectors & soft susy breaking.

Requiring tree-level separation of high (here Planck) and low (here GUT, EW,...) scales is a prerequisite to mitigate potential hierarchy problems, irrespective of the ensuing strength of susy breaking.

Repeating Soni & Weldon's exercise



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Approach seemingly straightforward:

$$K = \sum_{n=0}^N m_{p\ell}^n K_n(z, z^\dagger, \Phi, \Phi^\dagger),$$

$$W = \sum_{n=0}^M m_{p\ell}^n W_n(z, \Phi)$$

inject in V_F and require positive powers of $m_{p\ell}$ to be Φ, Φ^\dagger independent.

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BUT we stumbled on something...

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In this talk we focus on the simplest Kähler form

$$K = m_{pl}^2 z^{i*} z^i + \Phi^{a*} \Phi^a$$

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$$K = m_{pl}^2 z^{i*} z^i + \Phi^{a*} \Phi^a$$

$$V_F = e^{\frac{z^I z^{I*}}{m_{pl}^2}} \sum_{c=0}^{2M} V_{M,c}[z, z^\dagger, \Phi, \Phi^\dagger] m_{pl}^c + \mathcal{O}(m_{pl}^{-1}),$$

Back up

$$\begin{aligned}
 V_{M,c}[z, z^\dagger, \Phi, \Phi^\dagger] = & \sum_{n_-^{(0)} \leq n \leq n_+^{(0)}} \frac{\partial W_n}{\partial \Phi^a} \frac{\partial \bar{W}_{c-n}}{\partial \Phi^{a*}} + \\
 & \sum_{n_-^{(2)} \leq n \leq n_+^{(2)}} \left(\left(\frac{\partial W_n}{\partial z^i} + z^{i*} W_n \right) \left(\frac{\partial \bar{W}_{c-n+2}}{\partial z^{i*}} + z^i \bar{W}_{c-n+2} \right) \right. \\
 & \left. + \Phi^a \frac{\partial W_n}{\partial \Phi^a} \bar{W}_{c-n+2} + \Phi^{a*} \frac{\partial \bar{W}_n}{\partial \Phi^{a*}} W_{c-n+2} - 3W_n \bar{W}_{c-n+2} \right) \\
 + & \sum_{n_-^{(4)} \leq n \leq n_+^{(4)}} W_n \bar{W}_{c-n+4} \Phi^{a*} \Phi^a
 \end{aligned}$$

$$n_+^{(s)} = \min[M, c + s],$$

$$n_-^{(s)} = \max[0, c - M + s]$$

Back up

E.g. for $c = 2M - 1$:

$$\frac{\partial \bar{W}_M}{\partial \Phi^{a*}} \frac{\partial W_{M-1}}{\partial \Phi^a} + \text{h.c.} \sim_{\Phi} 0$$

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$$\{\Phi\} = \{\tilde{\Phi}^a, S^1\}$$

$$W(z, S, \tilde{\Phi}) = m_{pl} \left[W_{1,0}(z) + S^1 W_{1,1}(z) \right] + W_0(z, \tilde{\Phi}) + S^1 W_{0,1}(z)$$

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BUT Planck suppressed coupling of S^1 to the rest of the visible sector.

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where

$$W_1(z, S) = W_{1,0}(z) + \sum_{p \geq 1}^P W_{1,p}(z) \sum_{s \geq 1}^{n_p} \mu_{p_s}^* S^{p_s},$$

and

$$W_0(z, S, \tilde{\Phi}) = \sum_{q \geq 1}^k W_{0,q}(z) S^q + \Xi(\dots, \mathcal{U}_S^{pp_s} \dots; \dots, \tilde{\Phi}^a, \dots; \dots, z^i, \dots),$$

with

$$\mathcal{U}_S^{pp_s} \equiv \xi_{p_s}(z) S^{p_s} - \xi^{p_s}(z) S^{p_1} \quad \text{and} \quad \mu_{p_s} \xi_{p_s}(z) = \mu_{p_1} \xi^{p_s}(z)$$

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with

$$\mathcal{U}_S^{1p} \equiv \mu_1 S^p - \mu_p S^1$$

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- the S -fields should be SM singlets
- e.g. $\lambda S H_u \cdot H_d$, $\xi_F S$, $\frac{1}{2}\mu' S^2$, $\frac{1}{3}\kappa S^3$

$$\begin{array}{cccccccccccccccc} \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ \lambda \mathcal{U}_S^{ab} H_u \cdot H_d, & \xi_F^a S^a & + & \xi_F^b S^b, & \frac{1}{2}\mu' [\mathcal{U}_S^{ab}]^2, & \frac{1}{3}\kappa [\mathcal{U}_S^{ab}]^3 \end{array}$$

$$\mathcal{U}_S^{ab} = \xi_F^{a*} S^b - \xi_F^{b*} S^a$$

- the S -fields could be charged under (gauge) symmetries of secluded sectors \rightarrow interesting Yukawa structures $(\mathcal{U}_S^{ab})_L \cdot H (\mathcal{U}_S^{ab})_R$
- ...

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$$\begin{aligned} V_{\text{LE}}^{\text{NSWS}} &= \left| \frac{\partial \widehat{\Xi}}{\partial \widetilde{\Phi}^a} \right|^2 + m_{3/2}^2 |\widetilde{\Phi}^a|^2 \\ &+ m_{3/2} \left((A-3) \widehat{\Xi} \right. \\ &+ \left. \widetilde{\Phi}^a \frac{\partial \widehat{\Xi}}{\partial \widetilde{\Phi}^a} + \text{h.c.} \right) \\ &+ \mathcal{O}(m_{\text{pl}}^{-2}), \end{aligned}$$

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 &+ e^{|b_i|^2} M^2 \mathcal{A}_{qr} S^q S^{r*} \\
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 &+ e^{|b_i|^2} M^2 \mathcal{A}_{qr} S^q S^{r*} \\
 &+ e^{|b_i|^2} M^3 \left(((A + \langle A^{(S)} \rangle) - 2) a_q^* + A' \mu_q^* \right) S^q + \text{h.c.} \\
 &+ \mathcal{O}(m_{pl}^{-2}) ,
 \end{aligned}$$

$$A^{(S)} \equiv \frac{1}{M} \sum_q a_q S^{q*} = \frac{M_{11}}{M^2} \langle \omega_{11}(z) \rangle^* \sum_q \mu_q S^{q*}$$

Provisional conclusions and outlook

- separation of Planck and EW scales compatible with other structures than usually assumed.
- these structures suggest NNMSSM-like models, but with unusual SUSY breaking (including parametrically small hard breaking).
- can these be implemented into viable models (RGEs, mass spectrum, ...)?
- can they live better with the so far no SUSY experimental discovery?
- pheno? DM ? cosmo? → S.low.SUGRA project (IPHC, L2C, LUPM, APC)