Prospectives IPHC – cMSSM a non-natural choice

Michel Rausch de Traubenberg

Institut Pluridisciplinaire Hubert Curien
Département de Recherches Subatomiques
Groupe Théorie

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1. The context
2. Supersymmetry
   - Supersymmetry in brief
   - Supergravity in very brief
   - Supergravity breaking
3. Gravity induced supersymmetry breaking
   - Universality
   - Gravity induced supersymmetry breaking
4. Conclusion

The context

Standard Model of particles Physics

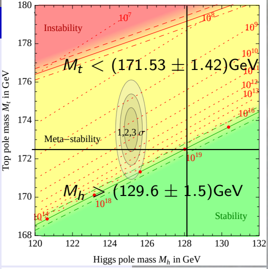
Advantages

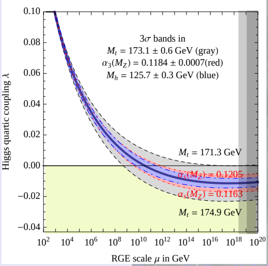
1. Explains **almost** all microscopic phenomena
2. Extremely **robust** theory
3. No **deviation** of the SM predictions in colliders

Disadvantages

- Many important problems are **unsolved**
  1. **Dark matter**
  2. Higgs mass (**hierarchy**)
  3. To many free parameters (**26**)
  4. **Incompatible** with general relativity
  5. *Etc.*
- Higgs + top **suggests** vacuum instability

  (D. Buttazzo, *et al.* arxiv.1307.353 [hep-ph]])





The context

It is strongly believed that the SM is not the ultimate theory

Extension of the SM

1. Three mains theories

   Supersymmetry/supergravity
   Grand-Unified Theories
   Extra-dimensions
   } String theory

2. Each has its **own predictions**
3. No indication of **new physics** in accelerators
4. How **robust** are the conclusions?
5. Are the conclusions **model dependent**?
6. Can we assume that such theory is **excluded**? **Confidence level**?
7. If signal of new physics is observed: to which theory it arises?

The MSSM and the cMSSM

1. Supersymmetry has been **highly studied**
2. **Minimal extension** of the SM: the MSSM

$\rightarrow$ To each **particle** one associate its supersymmetric **partner**

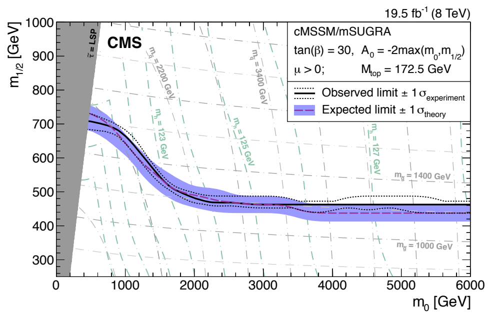
SM particles	spin	SUSY partners	spin
leptons	$s = 1/2$	sleptons	$s = 0$
quarks	$s = 1/2$	squarks	$s = 0$
gauge bosons	$s = 1$	gauginos	$s = 1/2$
two Higgses	$s = 0$	Higgsinos	$s = 1/2$

QN

3. Supersymmetry has to be **broken**
   - a The general MSSM has more than 100 free parameters
   - b cMSSM: assume **universality** at the GUT scale
   - c 4.5 new parameters at GUT scale $\Longrightarrow$ RGE's at TeV scale
     - 1 All the scalars have the same mass m_0
     - 2 All the gauginos have the same mass $m_{1/2}$
     - 3 All the trilinear couplings of the scalars are the equal A_0
     - 4 Ratio of the v.e.v. of the Higgs doublets $= \tan\beta$
     - 4.5 The sign of Higgs mixing parameter μ.

Constraints on the cMSSM

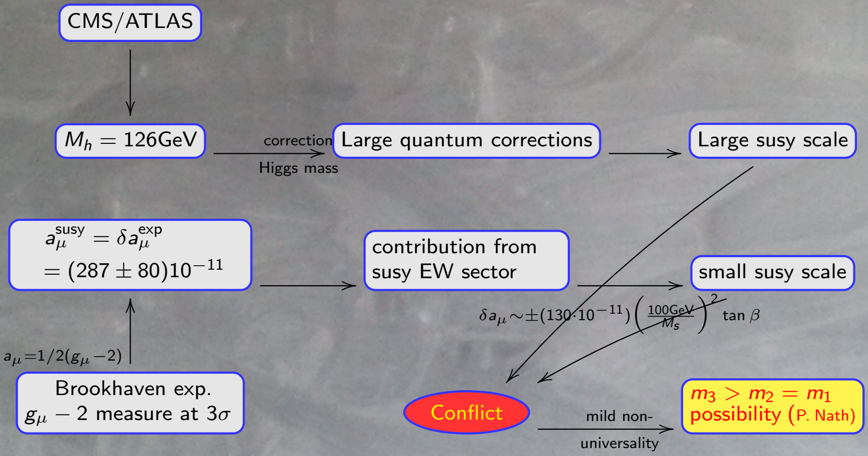
The cMSSM is very constrained and almost excluded



@CMS at 8TeV[arXiv:1502.04358v1 [hep-ex]])

... but the cMSSM is not natural

Tensions in the cMSSM: an example



P. Nath [arXiv:1501.01679 [hep-ph]]

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Supersymmetry in brief

- Supersymmetry is a **symmetry fermions-bosons**
- To any particle of the Standard $\rightarrow$ supersymmetric partner

Two types of superfields

Matter and Higgs particles

$\longrightarrow$ Chiral superfield $\Phi = (z, \chi, F)$

1. z = complex scalar field = **spin zero**
2. χ = left-handed Weyl spinor = **spin one-half**
3. F complex auxiliary field $\rightarrow$ scalar potential

Gauge particles

$\longrightarrow$ Vector superfield $V = (A_\mu, \lambda, D) \rightsquigarrow$ spinor superfield W_α

1. A_μ = gauge boson = **spin one**
2. λ = Majorana spinor = **spin one-half**
3. D real auxiliary field $\rightarrow$ **scalar potential**

Supersymmetry in brief

The Lagrangian

Field content

- Gauge group G : vector/spinor superfields V^a/W^a_α
- Matter multiplet : chiral superfields Φ^i — representation of G

Interactions — one basis function: the **Superpotential**

- Gauge invariant holomorphic functions **renormalisable**

$$W(\Phi^i) = \frac{1}{6}\lambda_{ijk}\Phi^i\Phi^j\Phi^k + \frac{1}{2}m_{ij}\Phi^i\Phi^j$$

→ Yukawa interaction
→ scalar potential

The Lagrangian

$$\mathcal{L} = \boxed{\int \mathrm{d}^2\theta \mathrm{d}^2\bar\theta \Phi^\dagger e^{-2gV}\Phi} + \Bigg(\boxed{\frac{1}{16g^2}\int \mathrm{d}^2\theta \frac{1}{16g^2} W^{a\alpha}W^b_\alpha \delta_{ab}} + \int \mathrm{d}^2\theta W(\Phi) + \mathrm{h.c.}\Bigg)$$

Supersymmetry in brief

Interactions

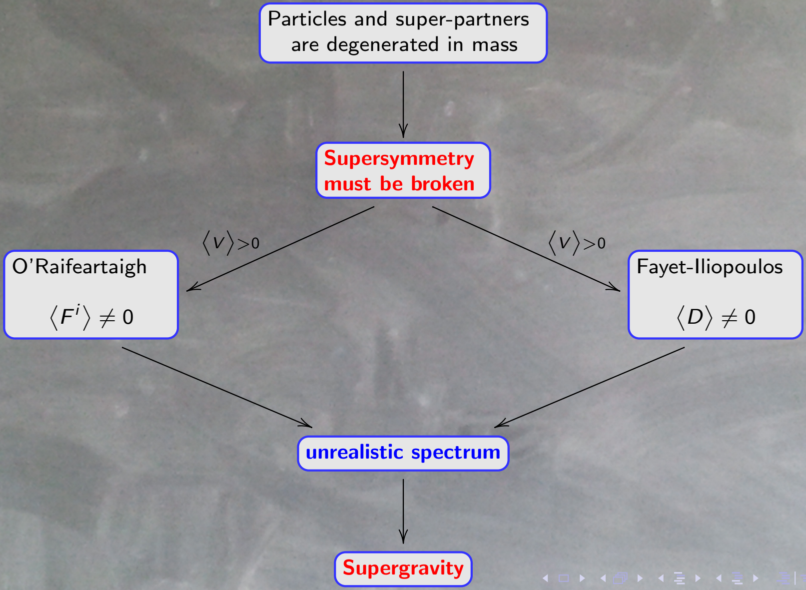
Scalar potential

$$V = F^i F_i^\dagger + \frac{1}{2} D^a D_a$$
$$= \frac{\partial W}{\partial \phi^i} \frac{\partial \bar{W}}{\partial \phi_i^\dagger} + \frac{1}{2} g^2 (\phi^\dagger T^a \phi)(\phi^\dagger T^b \phi)\delta_{ab}$$

The potential is positive $V \geq 0$

Yukawa interactions

$$\mathcal{L}_{\text{int.}} = -\frac{1}{2} \frac{\partial^2 W}{\partial \phi^i \partial \phi^j} \chi^i \cdot \chi^j - \frac{1}{2} \frac{\partial^2 \bar{W}}{\partial \phi_i^\dagger \partial \phi_j^\dagger} \bar{\chi}_j \cdot \bar{\chi}_j$$
$$-\frac{1}{2}(\lambda_{ijk} z^k \chi^i \cdot \chi^j + m_{ij} \chi^i \cdot \chi^j) + \text{h.c.}$$


Particles and super-partners are degenerated in mass
Supersymmetry must be broken
$\langle V \rangle > 0$
$\langle V \rangle > 0$
O'Raifeartaigh
$\langle F^i \rangle \neq 0$
Fayet-Iliopoulos
$\langle D \rangle \neq 0$
unrealistic spectrum
Supergravity

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Supergravity in very brief

- Supergravity is **gauged supersymmetry** $\Rightarrow$ Theory of **gravity**
- There is **several** theories of supergravity $\Longrightarrow$ **Minimal supergravity**

Minimal supergravity: Field content

- Matter/gauge superfields extend in supergravity
- Gauge group G : vector/spinor superfields V^a/W^a_α
  1. A^a_μ = gauge boson = **spin one**
  2. λ^a = Majorana spinor (gaugino) = **spin one-half**
  3. D^a real auxiliary field
- Matter multiplet : chiral superfields Φ^i
  1. z^i = complex scalar field = **spin zero**
  2. χ^i = left-handed Weyl spinor = **spin one-half**
  3. F^i complex auxiliary field
- Gravity multiplet
  1. $e_{\tilde{\mu}}{}^\nu$ = graviton = **spin two**
  2. $\psi_{\tilde{\mu}}$ = Majorana spin.-vect. (gravitino) = **spin three-half**
  3. M complex scalar auxiliary field
  4. $b_{\tilde{\mu}}$ real vector auxiliary field

Minimal supergravity: The Lagrangian

Interactions − three basis functions

- **Superpotential**: Gauge invariant holomorphic functions $W(\Phi^i)$
  1. Yukawa interactions
- **Kähler potential**: real function $K(\Phi^i, \Phi^\dagger_{i^*})$
  1. Kinetic interactions for matter fields
  2. Minimal case $K(\Phi, \Phi^\dagger) = \Phi^\dagger \Phi$
- **Gauge kinetic functions**: holomorphic functions $h_{ab}(\Phi)$
  1. Kinetic interactions for gauge fields
  2. Minimal case $f_{ab}(\Phi) = \delta_{ab}$

$$G = K + m_p^2 \ln \left| \frac{W}{m_p^3} \right|^2$$

The Lagrangian

$$\mathcal{L}_{\text{susy}} = \int \mathrm{d}^2\theta \mathrm{d}^2\bar\theta \Phi^\dagger e^{-2gV} \Phi + \int \mathrm{d}^2\theta W(\Phi) + \frac{1}{16g^2} \int \mathrm{d}^2\theta \, \delta_{ab} W^{a\alpha} W^b_\alpha + \text{h.c.} \, .$$

Renormalisable Lagrangian

Minimal supergravity: The Lagrangian

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$$G = K + m_p^2 \ln \left| \frac{W}{m_p^3} \right|^2$$

Non-Renormalisable Lagrangian

The Lagrangian

$$d^2\bar{\theta} = -\frac{1}{4}\bar{D}\cdot\bar{D}$$

$$K = \Phi^\dagger \Phi$$

$$\mathcal{L}_{susy} = -\frac{1}{8}\int d^2\theta\, \bar{D}\cdot\bar{D}\, K(\Phi^\dagger e^{-2gV}, \Phi) + \int d^2\theta W(\Phi) + \frac{1}{16g^2}\int d^2\theta f(\Phi)_{ab} W^{a\alpha} W^b_\alpha + \text{h.c.}\ .$$

Minimal supergravity: The Lagrangian

Interactions – three basis functions

- **Superpotential**: Gauge invariant holomorphic functions $W(\Phi^i)$
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$$G = K + m_p^2 \ln \left| \frac{W}{m_p^3} \right|^2$$

The Lagrangian

Coupling to gravity

$$\mathcal{L}_{\text{sugra}} = \frac{3}{8} \int \mathrm{d}^2\Theta \; \mathcal{E}(\bar{\mathcal{D}}\cdot\bar{\mathcal{D}} - 8\mathcal{R}) e^{-\frac{1}{3}K(\Phi^\dagger e^{-2gV}, \Phi)}$$

$$+ \int \mathrm{d}^2\Theta \; \mathcal{E} W(\Phi) + \frac{1}{16g^2} \int \mathrm{d}^2\Theta \; \mathcal{E} h(\Phi)_{ab} \mathcal{W}^{a\alpha} \mathcal{W}^b_\alpha + \text{h.c.} \; .$$

- After expansion **complicated** Lagrangian with **many terms**
- Gives supersymmetric Lagrangian in the limit where **gravity is neglected**
- The scalar potential is given by

$$V_{\text{susy}} = \frac{\partial W}{\partial \Phi^i} \frac{\partial \bar{W}}{\partial \Phi^\dagger_i} + \text{gauge part}$$

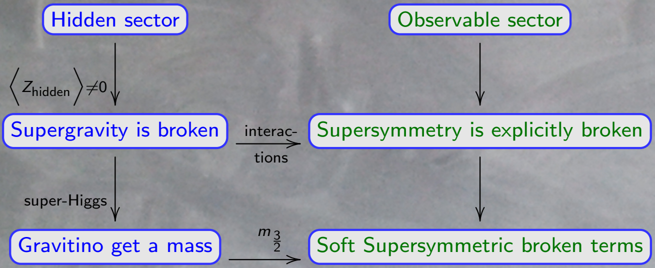
$$V = e^{\frac{1}{m_p^2} K(\Phi, \Phi^\dagger)} \left(\mathcal{D}_i W (K^{-1})^i{}_{j^*} \bar{\mathcal{D}}^{j^*} \bar{W} - \frac{3}{m_p^2} \left| W \right|^2 \right) + \text{gauge part}$$

1. The potential can be **positive, null or negative**
2. **different** that in **supersymmetry**
3. $\langle V \rangle \neq 0$ does not implies that supergravity is broken

- Supergravity is broken if the gravitino gets **massive**
  1. **super-Higgs mechanism**
  2. the gravitino mass is an order parameter.
- **No cosmological constant**: $\langle V \rangle = 0$

Supergravity breaking – Generalities

- It is more **natural** to break supersymmetry in the **supergravity** context
- **Several ways** to break supergravity
- All share a **common feature**
  - Two sectors: **hidden** and **observable** sectors
  - Supergravity is **broken** in the **hidden sector**
  - **Interactions** hidden/observable sector
    $\Longrightarrow$ break supersymmetry in the **observable** sector



Supergravity breaking – Generalities II

Supergravity breaking: major mechanisms

1. **Gravity mediated** supersymmetry breaking
   - → communicated to observable sector *via* **gravitational int.**
   - → **Kähler potential** essential
2. **Gauge mediated** supersymmetry breaking
   - → communicated to observable sector *via* **gauge int.**
   - → Introduction of **messengers and a singlet** (spurion)
   - → **Superpotential** essential (coupling messengers-spurion)
3. **Anomaly mediated** supersymmetry breaking
   - → Introduction of **compensating fields** with Weyl anomaly
   - → purely **quantum effects**

Supergravity breaking – Soft supersymmetric breaking terms

Soft supersymmetric breaking terms

1. Are generated by the mechanisms above
2. Break explicitly **supersymmetry** in the **observable** sector
3. $\rightarrow$ **Soft-supersymmetric** broken terms

   $\mapsto$ **good renormalisability properties**
4. Several types
   - a **Mass** for each **scalar** fields
   - c **Trilinear** and **bilinear** coupling terms for **scalar** fields
   - b **Mass** for each **gauge fermions**
5. Controled by the hidden sector and the **gravitino mass**
6. Are obtain at the **scale** where ~~Supergravity~~
7. Are computed at $\sim$ *TeV* using **RGE's**

$\mathcal{L}_{\text{sugra}} = \mathcal{L}_{\text{hidden}} + \mathcal{L}_{\text{obs}} + \mathcal{L}_{\text{hidden-obs}}$

scanned parameters $\Leftrightarrow$ class of hidden sectors

gravity neglected ~~supergravity~~

$\mathcal{L} = \mathcal{L}_{\text{susy}} + \mathcal{L}_{\text{soft}}$

assumptions

Phenomenological analysis

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- Two alternatives to do phenomenology of the MSSM
  1. **Choose a hidden** sector → compute the soft-susy term
  2. Put the soft susy-term by **hand** (assumptions)

The cMSSM

1. The hidden sector Z is the simplest as possible
2. No direct interactions with the observable sector Φ
3. The Kähler potential is diagonal

Renormalisability not necessary

$$\begin{aligned} K(Z, Z^\dagger, \Phi, \Phi^\dagger) &= K_{\text{hidden}}(Z, Z^\dagger) + K_{\text{obs}}(\Phi, \Phi^\dagger) \\ &= \boxed{Z^\dagger Z} + \Phi^\dagger \Phi \end{aligned}$$

4. The gauge kinetic functions are trivial

$$f_{ab}(Z, \Phi) = \delta_{ab} \boxed{f(Z)}$$

Universality

5. No-coupling *via* the superpotential

$$W(Z, \Phi) = \boxed{W_{\text{hidden}}(Z)} + W_{\text{MSSM}}(\Phi)$$

6. Fine tune of the parameters: vanishing cosmological constant

The cMSSM

Field content/cMSSM Lagrangian

Gauge bosons/Matter-Higgs

1. Gluons/gluinos $- SU(3)_c : G = (\underset{\sim}{8}, \underset{\sim}{1}, 0)$
2. W/Winos $- SU(2)_L : W = (\underset{\sim}{1}, \underset{\sim}{3}, 0)$
3. B/Bino$- U(1)_Y : B = (\underset{\sim}{1}, \underset{\sim}{1}, 0)$
4. sQuarks: $Q_L^i = (\underset{\sim}{3}, \underset{\sim}{2}, \frac{1}{6}), U^i = (\bar{\underset{\sim}{3}}, \underset{\sim}{1}, -\frac{2}{3}), D^i = (\bar{\underset{\sim}{3}}, \underset{\sim}{1}, \frac{1}{3})$
5. sLeptons: $L_L^i = (\underset{\sim}{1}, \underset{\sim}{2}, -\frac{1}{2}), e^i = (\bar{\underset{\sim}{1}}, \underset{\sim}{1}, 1), N^i = (\bar{\underset{\sim}{1}}, \underset{\sim}{1}, 0)$
6. Higgsino $H_U = (\underset{\sim}{1}, \underset{\sim}{2}, \frac{1}{2}), H_D = (\underset{\sim}{1}, \underset{\sim}{2}, -\frac{1}{2})$

At GUT scale 4.5 parameters

Superpotential/Soft-terms

$$W = -L\cdot H_D y_e E - Q\cdot H_D y_d D + Q\cdot H_U y_u U + L\cdot H_U y_n N \quad + NmN + \mu H_U\cdot H_D$$

$$V_{soft} = -\sum_i m_i^2 \Phi_i^\dagger \Phi^i \quad + \frac{1}{2}\left(M_1 \tilde{B}\cdot\tilde{B} + M_2 \tilde{W}\cdot\tilde{W} + M_3 \tilde{G}\cdot\tilde{G} + \text{h.c.}\right)$$

$$-\ell\cdot h_D A_e y_e e - q\cdot h_D A_d y_d d + q\cdot h_U A_u y_u u + \ell\cdot h_u A_n y_n n$$

$$+NmB' N + \mu B H_U\cdot H_D$$

UNIVERSALITY

More general (realistic?) hidden sector

Two important progress

No-scale supergravity

(Cremmer, Ferrara, Kounnas, Nanopoulos, Ellis, Lahanas, *etc*)

1. **Supergravity** is a theory of **gravity**
2. The potential at the minimum is the **cosmological constant**
3. No-scale supergravity: **geometry** ensures $\Lambda = 0$ (three level)
4. Two typical examples
   - a Only with a hidden sector
     $K(Z, Z^\dagger) + m_p^2 \ln|\frac{W(Z)}{m_p^3})|^2 = -3m_p^2 \ln(\frac{Z+Z^\dagger}{m_p^2})$
   - b With a hidden and an observable sector
     $K(Z, Z^\dagger, \Phi, \Phi^\dagger) + m_p^2 \ln|\frac{W(Z,\Phi)}{m_p^3})|^2 =$
     $-3\ln(\frac{Z+Z^\dagger}{m_p^2} - \frac{1}{3}\frac{1}{m_p^2}\Phi^i\Phi_i^\dagger)$

Two important progress II

Systematic in gravity induced supersymmetry breaking

(Soni-Weldon 1983)

1. They assume that there is a scale where ~~supersymmetry~~ $M_{\rm susy}$
2. They suppose a Taylor expansion

$$W(Z,\Phi) = \sum_{n=0}^{N} m_p^n W_n(Z,\Phi)$$

$$K(Z,Z^\dagger,,\Phi,\Phi^\dagger) = \sum_{n=0}^{N'} m_p^n K_n(Z,Z^\dagger,\Phi,\Phi^\dagger)$$

3. They show that we must have

$$\begin{aligned} W(Z,\Phi) &= m_p^2 W_2(Z) + m_p W_1(Z) + W_0(Z,\Phi) \\ K(Z,Z^\dagger,\Phi,\Phi^\dagger) &= m_p^2 K_2(Z,Z^\dagger) + m_p K_1(Z,Z^\dagger) \\ &\quad + K_0(Z,Z^\dagger,\Phi,\Phi^\dagger) \end{aligned}$$

The solutions of Soni-Weldon are incomplete:new solutions (Moultaka-MRT-Tant, in progress)

Application to the MSSM

- No-scale supergravity + SW result's + ⋯

(Giudice-Masiero, *etc* and Moultaka-MRT-Tant)

$$W_{\text{MSSM}} = \sum_f \left(G_3^f + m_f G_2^f \right) + \mu H_U \cdot H_D$$

$$\begin{aligned}
K(Z, Z^\dagger, \Phi, \Phi^\dagger) &= m_p^2 k(Z, \bar{Z}^\dagger) + \sum_f \Lambda_f(Z, Z^\dagger) \Phi^\dagger_{fi} \Phi^i_f \\
&+ \Lambda_h(Z, Z^\dagger) \left(H_U^\dagger H_U + H_D^\dagger H_D \right) \\
&+ F(Z, Z^\dagger) \left(H_D \cdot H_U + H_D^\dagger \cdot H_U^\dagger \right) \\
W(Z, \Phi) &= m_p^2 G_0(Z) + H_f(Z) G_3^f(\Phi) + M_f(Z) G_2^f(\Phi) \\
G_3^f(\Phi) &= -y_{e^f} L_L^f \cdot H_D E_L^f - y_{d^f} Q_L^f \cdot H_D D_L^f \\
&+ y_{n^f} L_L^f \cdot H_U N_L^f + y_{u^f} Q_L^f \cdot H_U U_L^f \\
G_2^f(\Phi) &= N_L^f N_L^f
\end{aligned}$$

No-scale condition for $k(Z, Z^\dagger) + 3 m_p^2 \ln \left| \frac{G_0(Z)}{m_p^3} \right|^2$

INTERESTING SOLUTION

New solution ≠ Soni-Weldon Moultaka-MRT-Tant

$$K(Z,Z^\dagger,\Phi,\Phi^\dagger) = m_p^2 k(Z,\bar{Z}^\dagger) + \sum_f \Lambda_f(Z,Z^\dagger)\Phi^\dagger_{fi}\Phi^i_f$$

$$+\Lambda_h(Z,Z^\dagger)H^\dagger_i H^i \quad +F(Z,Z^\dagger)\Big(H_D\cdot H_U + H^\dagger_D\cdot H^\dagger_U\Big)$$

$$W(Z,\Phi) = m_p^2 G_0(Z) + H_f(Z)G_3^f(\Phi) + M_f(Z)G_2^f(\Phi)$$

$$G_3^f(\Phi) = -y_{e^f} L^f_L\cdot H_D E^f_L - y_{d^f} Q^f_L\cdot H_D D^f_L$$

$$-y_{n^f} L^f_L\cdot H_D N^f_L + y_{u^f} Q^f_L\cdot H_U U^f_L$$

$$G_2^f(\Phi) = N^f_L N^f_L$$

- No-scale supergravity: $m_{\frac{3}{2}} = \left\langle G_0 e^{\frac{1}{2}k}\right\rangle$
- Vanishing of the cosmological constant

New solution
$\neq$ Soni-Weldon

$$K(Z, Z^\dagger, \Phi, \Phi^\dagger) = m_p^2 k(Z, \bar{Z}^\dagger) + \sum_f \Lambda_f(Z, Z^\dagger)\Phi^\dagger_{fi}\Phi^i_f$$

$$+ \Lambda_h(Z, Z^\dagger)H_i^\dagger H^i + F(Z, Z^\dagger)\Big(H_D \cdot H_U + H_D^\dagger \cdot H_U^\dagger\Big)$$

$$W(Z, \Phi) = m_p^2 G_0(Z) + H_f(Z) G_3^f(\Phi) + M_f(Z) G_2^f(\Phi)$$

$$G_3^f(\Phi) = -y_{e^f} L_L^f \cdot H_D E_L^f - y_{d^f} Q_L^f \cdot H_D D_L^f - y_{n^f} L_L^f \cdot H_D N_L^f + y_{u^f} Q_L^f \cdot H_U U_L^f$$

$$G_2^f(\Phi) = N_L^f N_L^f$$

Hierarchy-family mass: $\hat{y}_i^f = \left\langle \frac{e^{\frac{1}{2}k} H_f}{\Lambda_f \sqrt{\Lambda_h}} \right\rangle y_i^f$

$\neq$ Majorana mass for $R-$neutrinos: $m_f = \left\langle e^{\frac{1}{2}k} M_f/\Lambda_f \right\rangle \rightarrow$ See-saw

$$K(Z,Z^\dagger,\Phi,\Phi^\dagger) = m_p^2 k(Z,\bar{Z}^\dagger) + \sum_f \Lambda_f(Z,Z^\dagger)\Phi^\dagger_{fi}\Phi^i_f$$

$$+\Lambda_h(Z,Z^\dagger)H_i^\dagger H^i \quad +F(Z,Z^\dagger)\Big(H_D\cdot H_U + H_D^\dagger\cdot H_U^\dagger\Big)$$

$$W(Z,\Phi) = m_p^2 G_0(Z) + H_f(Z)G_3^f(\Phi) + M_f(Z)G_2^f(\Phi)$$

$$G_3^f(\Phi) = -y_{e^f}L_L^f\cdot H_D E_L^f - y_{d^f}Q_L^f\cdot H_D D_L^f$$

$$-y_{n^f}L_L^f\cdot H_D N_L^f \quad +y_{u^f}Q_L^f\cdot H_U U_L^f$$

$$G_2^f(\Phi) = N_L^f N_L^f$$

The $\mu-$term is generated naturally *à la Giudice-Masiero*

$$\mu = m_{\frac{3}{2}}\left\langle\frac{F}{\Lambda_h} - \tilde{\rho}_1^{\dagger i}\frac{\partial_i F}{\Lambda_h}\right\rangle = m_{\frac{3}{2}}\, d$$

Non-Universality

Superpotential/Kähler potential

1. **Three trilinear** soft-terms
   one for **each family**
2. **Four bilinear** soft-terms
   one for **each sneutrino**
   one for the **Higgses**
3. **Four scalar mass** square terms
   one **for each family**
   one for the **Higgses**

Gauge kinetic function

4. **Three gauginos mass** terms (~~one~~ if GUT)
   one for each **gauge group**

Controled by the gravitino mass $m_{\frac{3}{2}}$

Different hidden sectors ⇒ different boundary conditions
As *e.g.* the pMSSM or other possibilities

- The mechanism of **supergravity breaking** are very rich
  - **Gravity mediated** supersymmetry breaking
  - **Gauge mediated** supersymmetry breaking
  - **Anomaly mediated** supersymmetry breaking
  - Other mechanisms (**String/orbifolds** $\cdots$)
  - **Mixture** of several mechanisms
- Importance of the **hidden sector**
  - **By hand** for phenomenological purpose
  - **Top-down** justification: **String theory**?
- **Experimental exclusion** limits of supersymmetry **model independent**?
- **Supersymmetry** is not definitely ruled out **see** *e.g.*

  (H. Baer, V. Barger, M. Savoy [arXiv:1502.04127 [hep-ph]])
  - deep analysis of **naturalness** in the light of **recent datas** $\rightarrow$ **non-universality**
  - the essential **supergravity** scenarios **remains intact**

Motivation for supersymmetry

- Following J. Ellis ([arXiv:1501.05418 [hep-ph]]) and J. Bond
  007 reasons for supersymmetry

1. **measured values** of m_t and m_h.
2. **dark matter**
3. CP **violation** beyond CKM
4. **small size** of neutrino mass
5. New physics at Tev for **hierarchy** of masses
6. to have **inflation** (Higgs potential becomes negative at high energy)
7. to include **gravity**

Mechanism of gravity induced supersymmetry breaking studied for more than 30 years

↓

Soni-Weldon : INCOMPLETE

↓ *Moultaka* − *MRT* − *Tant*

New solutions

↓

Some with a new (cosmological sector)

↓

$$W(Z,\Phi,S) = \quad m_p\Big[W_1(Z)+S^pW_{1p}(Z)\Big] + \ W_0(Z,\Phi)+S^pW_{0p}(Z)$$
$$K(Z,\Phi,S) = m_p^2K_2(Z)+m_pK_1(Z)+G_1(Z,\Phi)+G_2(Z,S)$$

In progress

name	particle	susy partner	repr.
(s)quarks	$q^I_L = \begin{pmatrix} u^I_L \\ d^I_L \end{pmatrix}$ u^{Ic}_R d^{Ic}_R	$\tilde{q}^I_L = \begin{pmatrix} \tilde{u}^I_L \\ \tilde{d}^I_L \end{pmatrix}$ $\tilde{u}^{I\dagger}_R$ $\tilde{d}^{I\dagger}_R$	$(\underset{\sim}{\mathbf{3}}, \underset{\sim}{\mathbf{2}}, \frac{1}{6})$ $(\underset{\sim}{\bar{\mathbf{3}}}, \underset{\sim}{\mathbf{1}}, -\frac{2}{3})$ $(\underset{\sim}{\bar{\mathbf{3}}}, \underset{\sim}{\mathbf{1}}, \frac{1}{3})$
(s)leptons (s)neutrinos	$\ell^I_L = \begin{pmatrix} \nu^I_L \\ e^I_L \end{pmatrix}$ e^{Ic}_R ν^{Ic}_R	$\tilde{\ell}^I_L = \begin{pmatrix} \tilde{\nu}^I_L \\ \tilde{e}^I_L \end{pmatrix}$ $\tilde{e}^{I\dagger}_R$ $\tilde{\nu}^{I\dagger}_R$	$(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{2}}, -\frac{1}{2})$ $(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{1}}, 1)$ $(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{1}}, 0)$
Higgs(inos)	$H_1 = \begin{pmatrix} H_{10} \\ H_{1-} \end{pmatrix}$ $H_2 = \begin{pmatrix} H_{2+} \\ H_{20} \end{pmatrix}$	$\tilde{H}_1 = \begin{pmatrix} \tilde{H}_{10} \\ \tilde{H}_{1-} \end{pmatrix}$ $\tilde{H}_2 = \begin{pmatrix} \tilde{H}_{2+} \\ \tilde{H}_{20} \end{pmatrix}$	$(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{2}}, -\frac{1}{2})$ $(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{2}}, \frac{1}{2})$
boson-B bino	B	$\tilde{B}$	$(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{1}}, 0)$
bosons-W winos	W	$\tilde{W}$	$(\underset{\sim}{\mathbf{1}}, \underset{\sim}{\mathbf{3}}, 0)$
gluons gluinos	g	$\tilde{g}$	$(\underset{\sim}{\mathbf{8}}, \underset{\sim}{\mathbf{1}}, 0)$