

CONSTRAINTS FROM SUSY BREAKING IN SUPERGRAVITY THEORIES

Claudio Scrucca

University of Neuchâtel

- SUSY breaking in SUGRA scenarios.
- SUGRA models with chiral multiplets.
- Flatness and stability constraints.
- Factorizable scalar manifolds.
- Symmetric scalar manifolds.
- Moduli in string models.

Gomez-Reino, Scrucca (hep-th/0602246)

Gomez-Reino, Scrucca (will appear soon)

SUSY BREAKING AND SUGRA

Direct spontaneous **SUSY** breaking implies, in a renormalizable and anomaly-free theory with rigid **SUSY**, a sum rule on the mass spectrum:

$$\text{STr } M^2 = \sum_J (-1)^{2J} (2J + 1) m_J^2 = 0$$

This predicts generically that some superparticle is lighter than its ordinary partner particle, in contradiction with experimental observation.

The standard paradigm to evade this difficulty is to assume that **SUSY** breaking occurs spontaneously in a **hidden** sector with fields Φ_i and is transmitted to the **visible** sector with fields Q_a only indirectly, through some suppressed interactions.

The effect of **SUSY** breaking on the visible sector can be parametrized through super-renormalizable **soft breaking terms**, which depend both on the details of the hidden sector theory and on the mediation mechanism.

The relevant effective Lagrangian for phenomenology has then the general form:

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

A natural mediation mechanism is provided by gravitational interactions, which have a scale M_P . The general setup then becomes that of **SUGRA**, with local **SUSY**.

SUSY breaking occurs spontaneously at some scale $M \ll M_P$ in the hidden sector and is transmitted to the visible sector through gravitational interactions.

The microscopic theory might be some superstring model. But below M_P , and in particular at M , this can be effectively described by a non-renormalizable **SUGRA** theory.

The **soft** terms originate from higher-dimensional operators that mix visible fields Q_a to hidden fields Φ_i and are suppressed by powers of M_P , and their scale is

$$m_{\text{soft}} \sim \frac{M^2}{M_P}$$

Chamseddine, Arnowitt, Nath
Barbieri, Ferrara, Savoy
Hall, Lykken, Weinberg

The main delicate features that are needed in order to get a satisfactory situation are:

- Soft terms with $m_{\text{soft}} \sim M_{\text{EW}}$ and peculiarities.
- Cosmological constant with $M_{\text{CC}} \ll M_{\text{EW}}$.
- Hidden scalars with $m > M_{\text{EW}}$ and stable.

CHIRAL SUGRA MODELS

A **SUGRA** theory with N chiral multiplets Φ_i is specified by a real function G . Setting $M_{\text{P}} = 1$, this can be written as

$$G(\Phi_i, \Phi_i^\dagger) = K(\Phi_i, \Phi_i^\dagger) + \log W(\Phi_i) + \log \bar{W}(\Phi_i^\dagger)$$

This decomposition is however ambiguous, due to the **Kähler** symmetry changing $K \rightarrow K + F + \bar{F}$ and $W \rightarrow e^{-F} W$.

Mixed holomorphic/antiholomorphic derivatives of G depend only on K and define a **Kähler geometry** for the manifold parametrized by the scalars ϕ^i . The **metric**, the **Christoffel connection** and the **Riemann tensor** are given by:

$$g_{i\bar{j}} = G_{i\bar{j}}$$

$$\Gamma_{ij}^k = G_{ij}^k, \quad \Gamma_{\bar{i}\bar{j}}^{\bar{k}} = G_{\bar{i}\bar{j}}^{\bar{k}}$$

$$R_{i\bar{j}p\bar{q}} = G_{i\bar{j}p\bar{q}} - G_{ip}^r G_{\bar{j}\bar{q}r}$$

Pure holomorphic or antiholomorphic derivatives of G depend instead also on W , and determine the way **SUSY** is broken. In particular, the auxiliary fields F^i are given simply by:

$$F^i = e^{G/2} G^i$$

Cremmer, Julia, Scherk, Ferrara, Girardello, Van Nieuwenhuizen
Bagger, Witten

The scalars ϕ^i have a wave function factor given by $Z_{i\bar{j}} = g_{i\bar{j}}$ and a potential, which determines their **vev** and **mass** and controls spontaneous **SUSY** breaking, of the form:

$$V = e^G (G^k G_k - 3)$$

The **flatness** condition of vanishing cosmological constant is that $V = 0$ on the vacuum and implies that at that point:

$$g_{i\bar{j}} G^i G^{\bar{j}} = 3$$

The first derivatives of the potential controlling its variations can be computed as $\delta_i = \nabla_i V$ and are given by:

$$\delta_i = e^G (G_i + G^k \nabla_i G_k)$$

The **stationarity** conditions defining extrema of the potential are $\delta_i = 0$ and imply:

$$G_i + G^k \nabla_i G_k = 0$$

The two types of second derivatives of the potential controlling the squared masses can be computed as $m_{i\bar{j}}^2 = \nabla_i \nabla_{\bar{j}} V$ and $m_{ij}^2 = \nabla_i \nabla_j V$, and one easily finds:

$$m_{i\bar{j}}^2 = e^G (g_{i\bar{j}} + \nabla_i G^k \nabla_{\bar{j}} G_k - R_{i\bar{j}p\bar{q}} G^p G^{\bar{q}})$$

$$m_{ij}^2 = e^G \left(\nabla_i G_j + \nabla_j G_i + \frac{1}{2} G^k \{ \nabla_i, \nabla_j \} G_k \right)$$

The **stability** condition is that the $2N$ -dimensional squared-mass matrix is positive definite:

$$m_0^2 = \begin{pmatrix} m_{i\bar{j}}^2 & m_{ij}^2 \\ m_{i\bar{j}}^2 & m_{ij}^2 \end{pmatrix} > 0$$

The only systematic way to determine the constraints that this implies is to study the mass eigenvalues.

The fermions ψ^i split into 1 Goldstino combination $\psi = G_i \psi^i$ and $N - 1$ physical combinations $\tilde{\psi}^i$. They have wave-function factor $\tilde{Z}_{i\bar{j}} = g_{i\bar{j}}$, and their mass is encoded in:

$$\tilde{m}_{ij} = e^G \left(\nabla_i G_j + \frac{1}{3} G_i G_j \right)$$

More precisely, the $2N$ -dimensional mass matrix is given by

$$m_{1/2} = \begin{pmatrix} 0 & \tilde{m}_{ij} \\ \tilde{m}_{i\bar{j}} & 0 \end{pmatrix}$$

The graviton and gravitino $h^{\mu\nu}$ and ψ^μ have wave-function factors $Z_2 = 1$ and $Z_{3/2} = 1$, and masses:

$$m_2^2 = 0, \quad m_{3/2} = e^{G/2}$$

The supertrace of the squared mass matrix for the whole theory is found to be:

$$\text{STr} M^2 = 2 e^G \left(N - 1 - R_{i\bar{j}} G^i G^{\bar{j}} \right)$$

FLATNESS AND STABILITY CONSTRAINTS

It would be interesting to understand better what flatness and stability imply on G . More precisely, it would be very useful to derive a condition concerning only K and the geometry, independently of W and the mechanism of SUSY breaking.

Our strategy is to impose the flatness condition $V = 0$ and look for some simpler condition that is only necessary and in general not sufficient for having stability with $m_0^2 > 0$.

The crucial point is that all the upper-left submatrices of m_0^2 must also be positive definite. In particular, the N -dimensional submatrix $m_{i\bar{j}}^2$ should be positive definite:

$$m_{i\bar{j}}^2 > 0$$

This condition means that $\forall z^i$ one must have $m_{i\bar{j}}^2 z^i \bar{z}^{\bar{j}} > 0$. One can then look for a specific z^i that leads to a particularly simple condition. The right choice is $z^i = G^i$, for which:

$$m_{i\bar{j}}^2 G^i G^{\bar{j}} = e^G \left(6 - R_{i\bar{j}p\bar{q}} G^i G^{\bar{j}} G^p G^{\bar{q}} \right)$$

The corresponding necessary condition $m_{i\bar{j}}^2 G^i G^{\bar{j}} > 0$ reduces then to the extremely simple curvature constraint:

$$R_{i\bar{j}p\bar{q}} G^i G^{\bar{j}} G^p G^{\bar{q}} < 6$$

Note that the special direction $z^i = G^i$ considered to derive $m_{i\bar{j}}^2 G^i G^{\bar{j}} > 0$ for the scalars corresponds to the direction of the Goldstino for the fermions, and $\tilde{m}_{ij} G^i G^j = 0$.

Summarizing, a stationary point can lead to a satisfactory situation only if the following two conditions are satisfied:

Flatness: $g_{i\bar{j}} G^i G^{\bar{j}} = 3$ (necessary & sufficient)

Stability: $R_{i\bar{j}p\bar{q}} G^i G^{\bar{j}} G^p G^{\bar{q}} < 6$ (necessary)

The tensors $g_{i\bar{j}}$ and $R_{i\bar{j}p\bar{q}}$ depend only on K and characterize the geometry. The vectors G^i depend also on W and control the **SUSY** breaking direction, since $G^i = F^i / m_{3/2}$.

For a given geometry, the flatness condition determines the overall amount of **SUSY** breaking, and the stability condition constrains its direction to lie with a certain cone.

To solve the conditions, one must first determine the direction that minimizes $R_{i\bar{j}p\bar{q}} G^i G^{\bar{j}} G^p G^{\bar{q}}$ for fixed $g_{i\bar{j}} G^i G^{\bar{j}}$, and then check how far apart from it the former stays small enough.

This variational problem is hard to solve in full generality. However, it is possible to obtain very simple and strong results for the subclass of models based on spaces that are **factorizable** or **symmetric**.

Notice finally that the flatness and stability conditions refer to a particular stationary point. It is then extremely useful to switch to normal coordinates around that point.

These special coordinates are defined in the usual way by a holomorphic vielbein e_i^J and its inverse e_J^i , which allow to make the metric tensor trivial.

In these coordinates, the metric and the Riemann tensors are given by:

$$\delta_{I\bar{J}} = e_I^r e_{\bar{J}}^{\bar{s}} g_{r\bar{s}}$$

$$R_{I\bar{J}P\bar{Q}} = e_I^r e_{\bar{J}}^{\bar{s}} e_P^t e_{\bar{Q}}^{\bar{u}} R_{r\bar{s}t\bar{u}}$$

The new variables of the problem are correspondingly:

$$G^I = e_r^I G^r$$

The flatness and stability conditions defining the problem can then be rewritten simply as:

Flatness: $\delta_{I\bar{J}} G^I G^{\bar{J}} = 3$

Stability: $R_{I\bar{J}P\bar{Q}} G^I G^{\bar{J}} G^P G^{\bar{Q}} < 6$

FACTORIZABLE SPACES

Suppose that \mathcal{M} is a product of N 1-dimensional manifolds. The function K splits then into a sum of terms depending on a single field, while W can instead still be arbitrary:

$$K = \sum_k K^{(k)}(\Phi_k, \Phi_k^\dagger)$$

$$W = W(\Phi_1, \dots, \Phi_n)$$

This assumption represents a Kähler-invariant constraint on G , implying that all its mixed holomorphic/antiholomorphic off-diagonal derivatives vanish.

In this situation, $g_{i\bar{j}}$ and $R_{i\bar{j}p\bar{q}}$ become both diagonal and have only N non-vanishing components. This simplifies enough to problem to solve it exactly.

The non-vanishing components of the metric are $g_{i\bar{i}} = G_{i\bar{i}}$, and those of the curvature tensor are related to these by:

$$R_{i\bar{i}i\bar{i}} = R_i g_{i\bar{i}}^2$$

where the crucial parameters are the N curvature scalars R_i associated to each complex scalar field:

$$R_i = \frac{G_{i\bar{i}i\bar{i}}}{G_{i\bar{i}}^2} - \frac{G_{i\bar{i}i\bar{i}} G_{i\bar{i}i\bar{i}}}{G_{i\bar{i}}^3}$$

In flat coordinates, the Riemann tensor has then the form:

$$R_{I\bar{J}P\bar{Q}} = \begin{cases} R_i, & \text{if } I = J = P = Q \\ 0, & \text{otherwise.} \end{cases}$$

The two flatness and stability conditions derived before then simplify to the following expressions:

$$\text{Flatness: } \sum_k \Theta_k^2 = 1$$

$$\text{Stability: } \sum_k R_k \Theta_k^4 < \frac{2}{3}$$

in terms of the N real and positive variables

$$\Theta_i = \frac{1}{\sqrt{3}} |G^I|$$

It is now easy to show that for $R_i > 0$ these constraints admit solutions only if the following **curvature bound** is satisfied:

$$\sum_k R_k^{-1} > \frac{3}{2}$$

The **SUSY** breaking direction must lie in a certain **Goldstino cone** specified by the curvature scalars. Its **axis** is the preferred direction minimizing the quartic curvature form:

$$\Theta_i^0 = \sqrt{\frac{R_i^{-1}}{\sum_k R_k^{-1}}}$$

Its **solid angle** grows with the excess of the effective inverse curvature $\sum_k R_k^{-1}$ with respect to the threshold $3/2$.

More precisely, the allowed configurations correspond to a bounded domain in the space of variables:

$$\Theta_i \in [\Theta_i^-, \Theta_i^+]$$

One easily finds:

$$\Theta_i^+ = \begin{cases} \sqrt{\frac{R_i^{-1} + \sqrt{\frac{2}{3} R_i^{-1} \left(\sum_{k \neq i} R_k^{-1} \right) \left(\sum_k R_k^{-1} - \frac{3}{2} \right)}}{\sum_k R_k^{-1}}}, & R_i^{-1} < \frac{3}{2} \\ 1, & R_i^{-1} > \frac{3}{2} \end{cases}$$

$$\Theta_i^- = \begin{cases} \sqrt{\frac{R_i^{-1} - \sqrt{\frac{2}{3} R_i^{-1} \left(\sum_{k \neq i} R_k^{-1} \right) \left(\sum_k R_k^{-1} - \frac{3}{2} \right)}}{\sum_k R_k^{-1}}}, & \sum_{k \neq i} R_k^{-1} < \frac{3}{2} \\ 0, & \sum_{k \neq i} R_k^{-1} > \frac{3}{2} \end{cases}$$

A given Θ_i can become as large as 1 only if its curvature satisfies $R_i^{-1} > 3/2$, and as low as 0 only if the curvatures of the remaining fields satisfy $\sum_{k \neq i} R_k^{-1} > 3/2$.

The relevance of a particular chiral multiplet Φ_i for SUSY breaking depends thus on the size of the corresponding inverse curvature R_i^{-1} with respect to the threshold value $3/2$.

SYMMETRIC SPACES

Suppose that \mathcal{M} is a coset space G/H , where G is a group of global isometries and H a local stability group. The function K has then some special form, but W can be arbitrary:

$$K = K^{(G/H)}(\Phi_1, \Phi_1^\dagger, \dots, \Phi_n, \Phi_n^\dagger)$$

$$W = W(\Phi_1, \dots, \Phi_n)$$

The metric and curvature tensors are G -invariant and there are relations among their components. The problem simplifies then again sufficiently much to be able to solve it exactly.

For all the possible coset Kähler manifolds, the components of the metric and the Riemann tensor are somehow related:

$$R_{i\bar{j}p\bar{q}} \text{ related to } g_{r\bar{s}}$$

Calabi, Vesentini

The crucial ingredients are in this case the overall scale R_{all} of the curvature and the group structure of the space.

In flat coordinates, the Riemann tensor has in these cases a particularly simple structure of the form:

$$R_{I\bar{J}P\bar{Q}} = G\text{-invariant combination} \\ \text{of } H\text{-invariant } \delta\text{'s}$$

Generalized spheres

Suppose that there are $N = 1 + q$ fields Φ_i and

$$K = -\frac{2}{R_{\text{all}}} \ln \left(1 - \sum_i \Phi_i \Phi_i^\dagger \right)$$

The corresponding scalar manifold is the Kählerian analogue of the Riemannian sphere:

$$\mathcal{M} = \frac{SU(1, 1 + q)}{U(1) \times SU(1 + q)}$$

The Riemann tensor in normal coordinates takes in this case the very simple form

$$R_{I\bar{J}P\bar{Q}} = \frac{R_{\text{all}}}{2} (\delta_{I\bar{J}} \delta_{P\bar{Q}} + \delta_{I\bar{Q}} \delta_{P\bar{J}})$$

The two flatness and stability conditions can then be rewritten in the simple form

$$\text{Flatness: } \Theta^2 = 1$$

$$\text{Stability: } R_{\text{all}} \Theta^4 < \frac{2}{3}$$

in terms of just 1 real and positive variable

$$\Theta = \frac{1}{\sqrt{3}} \sqrt{\sum_k |G^K|^2}$$

The situation is then as for 1 field with $R = R_{\text{all}}$:

$$R_{\text{all}}^{-1} > \frac{3}{2}$$

Unitary Grassmannians

Suppose that there are $N = p(p + q)$ fields Φ_{ia} and

$$K = -\frac{2}{R_{\text{all}}} \ln \det \left(\delta_{i\bar{j}} - \sum_a \Phi_{ia} \Phi_{ja}^\dagger \right)$$

The corresponding scalar manifold is the unitary Grassmannian manifold

$$\mathcal{M} = \frac{SU(p, p + q)}{U(1) \times SU(p) \times SU(p + q)}$$

The Riemann tensor in normal coordinates takes in this case the following form

$$R_{IA\bar{J}\bar{B}PC\bar{Q}\bar{D}} = \frac{R_{\text{all}}}{2} \left(\delta_{I\bar{J}} \delta_{P\bar{Q}} \delta_{A\bar{D}} \delta_{C\bar{B}} + \delta_{I\bar{Q}} \delta_{P\bar{J}} \delta_{A\bar{B}} \delta_{C\bar{D}} \right)$$

The two conditions reduce then simply to

$$\text{Flatness: } \sum_k \Theta_k^2 = 1$$

$$\text{Stability: } \sum_k R_{\text{all}} \Theta_k^4 < \frac{2}{3}$$

in terms of the p real and positive variables

$$\Theta_i = \frac{1}{\sqrt{3}} \left| \text{Eigenvalue}_i(G^{IA}) \right|$$

The situation is then as for p fields with $R_i = R_{\text{all}}$:

$$R_{\text{all}}^{-1} > \frac{3}{2p}$$

Orthogonal Grassmannians

Suppose that there are $N = 2 + q$ fields Φ_i and

$$K = -\frac{2}{R_{\text{all}}} \ln \left(1 - 2 \sum_i \Phi_i \Phi_i^\dagger + \sum_{i,j} (\Phi_i \Phi_j^\dagger)^2 \right)$$

The corresponding scalar manifold is the orthogonal Grassmannian manifold

$$\mathcal{M} = \frac{SO(2, 2 + q)}{SO(2) \times SO(2 + q)}$$

The Riemann tensor in normal coordinates takes in this case the form

$$R_{I\bar{J}P\bar{Q}} = \frac{R_{\text{all}}}{2} \left(\delta_{I\bar{J}} \delta_{P\bar{Q}} + \delta_{I\bar{Q}} \delta_{P\bar{J}} - \delta_{IP} \delta_{\bar{J}\bar{Q}} \right)$$

The two conditions reduce then simply to

$$\text{Flatness: } \Theta_+^2 + \Theta_-^2 = 1$$

$$\text{Stability: } R_{\text{all}} \left(\Theta_+^4 + \Theta_-^4 \right) < \frac{2}{3}$$

in terms of the 2 real and positive variables

$$\Theta_{\pm} = \frac{1}{\sqrt{6}} \sqrt{\sum_k |G^K|^2 \pm \sqrt{\left(\sum_k |G^K|^2 \right)^2 - \left| \sum_k (G^K)^2 \right|^2}}$$

The situation is then as for 2 fields with $R_i = R_{\text{all}}$:

$$R_{\text{all}}^{-1} > \frac{3}{4}$$

MODULI IN STRING MODELS

In *string* models, a natural candidate for the hidden sector is the one containing the neutral *moduli* controlling the coupling strength and the compactification geometry, and possibly also the *Wilson lines* of the hidden gauge groups.

Kaplunovsky, Louis

In the simplest models, the scalar manifold characterizing the moduli sector is symmetric and sometimes also factorizable. This is due to the fact that this sector emerges as a projection of a *SUSY* theory in 10 dimension.

The scalar manifold is a Kähler submanifold of the space that would occur by compactifying on a T^6 . With a hidden gauge group of rank s , this has the form

$$\mathcal{M} = \frac{SU(1,1)}{U(1)} \times \frac{SO(6,6+s)}{SO(6) \times SO(6+s)}$$

Narain

The first factor is associated to the universal dilaton S , and is always present. The second factor is instead spanned by the Kähler moduli T_p , the complex structure moduli U_q , and the Wilson lines Z_a , and gets in general reduced.

Minimal moduli space

The simplest situation for each modulus Φ_i is that

$$K_i = -n_i \ln(\Phi_i + \Phi_i^\dagger)$$

Witten

This corresponds to the simplest symmetric space:

$$\mathcal{M}_i = \frac{SU(1, 1)}{U(1)}$$

The curvature scalar is:

$$R_i = \frac{2}{n_i}$$

Unitary enhancement by Wilson lines

Certain moduli Φ_i can mix to some number q_i of related Wilson lines X_{a_i} , and these $1 + q_i$ fields have then

$$K_i = -n_i \ln \left(\Phi_i + \Phi_i^\dagger - \sum_{a_i} X_{a_i}^\dagger X_{a_i} \right)$$

Ellis, Kounnas, Nanopoulos

Ferrara, Kounnas, Porrati

The corresponding scalar manifold is given by:

$$\mathcal{M}_i = \frac{SU(1, 1 + q_i)}{U(1) \times SU(1 + q_i)}$$

This is a generalized sphere, which behaves as 1 copy of the minimal geometry for the flatness and stability constraints, with curvature scale:

$$R_i = \frac{2}{n_i}$$

Unitary enhancement by extra moduli

A group of p_r moduli with the same n_r can get enhanced to a matrix of p_r^2 moduli $\Phi_{i_r j_r}$. These p_r^2 fields have then

$$K_r = -n_r \ln \det \left(\Phi_{i_r j_r} + \Phi_{i_r j_r}^\dagger \right)$$

Ferrara, Kounnas, Porrati

The corresponding scalar manifold is:

$$\mathcal{M}_r = \frac{SU(p_r, p_r)}{U(1) \times SU(p_r) \times SU(p_r)}$$

This is a unitary Grassmannian space, which behaves as p_r copies of the minimal geometry for the flatness and stability constraints, with overall curvature:

$$R_r = \frac{2}{n_r}$$

Unitary enhancement by Wilson lines and extra moduli

A group of p_r moduli with the same n_r can get enhanced to p_r^2 moduli $\Phi_{i_r j_r}$ and also couple to some number $p_r q_r$ of related Wilson lines $X_{i_r a_r}$. These $p_r(p_r + q_r)$ fields have then

$$K_r = -n_r \ln \det \left(\Phi_{i_r j_r} + \Phi_{i_r j_r}^\dagger - \sum_{a_r} X_{i_r a_r}^\dagger X_{j_r a_r} \right)$$

Ferrara, Kounnas, Porrati

The corresponding scalar manifold is:

$$\mathcal{M}_r = \frac{SU(p_r, p_r + q_r)}{U(1) \times SU(p_r) \times SU(p_r + q_r)}$$

This is again a unitary Grassmannian space, which still behaves as p_r copies of the minimal geometry for the flatness and stability constraints, with overall curvature scale given by:

$$R_r = \frac{2}{n_r}$$

Orthogonal enhancement by matter

A pair of 2 moduli ϕ_{1r} and ϕ_{2r} with common n_r can also mix in more peculiar and synchronized way to a number q_r of related Wilson lines X_{a_r} . The $2 + q_r$ fields that are involved are then described by:

$$K_r = -n_r \ln \left(\left(\Phi_{1r} + \Phi_{1r}^\dagger \right) \left(\Phi_{2r} + \Phi_{2r}^\dagger \right) - \sum_{a_r} \left(X_{a_r} + X_{a_r}^\dagger \right)^2 \right)$$

Derendinger, Kounnas, Petropoulos, Zwirner

The corresponding scalar manifold has in this case a different structure and is given by:

$$\mathcal{M}_r = \frac{SO(2, 2 + q_r)}{SO(2) \times SO(2 + q_r)}$$

This is an orthogonal Grassmannian space, which behaves as 2 copies of the minimal geometry for the flatness and stability constraints, with an overall curvature given by:

$$R_r = \frac{2}{n_r}$$

Flatness and stability constraints

The structure of the flatness and stability constraints for string moduli spaces is controlled by the minimal factorizable and symmetric geometry.

All the enhancements that we have analyzed just reshuffle the relevant combinations of fields, and do not allow to alleviate the resulting constraints for viable SUSY breaking.

The crucial parameters for these constraints are the numerical coefficients n_i controlling the curvature associated to each modulus Φ_i , with $R_i = 2/n_i$.

The necessary condition $\sum_k R_k^{-1} > 3/2$ on the curvatures does then imply the following restriction on these coefficients n_i :

$$\sum_k n_k > 3$$

The Goldstino cone is also entirely specified in terms of the parameters n_i , and puts very severe restrictions on the relative sizes of the auxiliary fields F_i . In particular, one finds that:

$$|F_i| : \begin{cases} \text{bounded by above if } n_i < 3 \\ \text{bounded by below if } \sum_{k \neq i} n_k < 3 \end{cases}$$

CONCLUSIONS AND OUTLOOK

- In **SUGRA** models with only chiral multiplets, there exist necessary conditions for stability that strongly constrain the curvature of the geometry and the **SUSY** breaking direction.
- The form of these constraints can be worked out in full detail for factorizable and symmetric geometries, as those occurring for instance in the moduli sector of string models.
- It would be of great interest to generalize this study to models involving also vector multiplets gauging isometries of the scalar manifold.