Simple Metastable de Sitter Vacua in *N*=2 Supergravity

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Cosmology versus N > 2 supergravity

Cosmology in supergravity and string theory is hard, both top-down and bottom-up. See the talks by McAllister, Baumann, Tye, Dall'Agata...

The special geometries appearing in $N > 2$ supergravity are sufficiently constraining that metastable de Sitter vacua ($V > 0$) are very difficult to find.

In fact, there are no-go theorems forbidding de Sitter vacua in certain N=2 supergravity theories. Cremmer et al '85, Gomez-Reino, Louis & Scrucca '08

Pre-2013 there was **only 1 set of examples** of metastable de Sitter vacua in N=2 supergravity and it utilised complicated ingredients. Fre, Trigiante & Van Proeyen '03

We have constructed simple examples of metastable de Sitter vacua in N=2 supergravity with one hypermultiplet and one Abelian vector multiplet.

de Sitter no-go theorems - only vectors or only hypers

N=2 supergravity with only Abelian vectors and constant FI terms **or** only hypers does not have metastable de Sitter vacua. Cremmer et al '85, Gomez-Reino, Louis & Scrucca '08

This can be seen by considering the averaged scalar mass matrix along some clever directions (e.g. sGoldstino - the scalar partner of the Goldstino).

$$m^2 = m^2_{i\bar{\jmath}} s^i s^{\bar{\jmath}}$$

Some linear algebra shows that this quantity gives an upper bound on the lightest scalar mass (noting eigenvalue repulsion).

The stationarity conditions plus the definitions of the Riemann tensors for the 2 special geometries imply that m^2 is fixed by the value of the potential:

$$m^2 \leq -2V \qquad \textbf{\textit{Negative}} \qquad m^2 \leq -\frac{1}{3} m^2_{3/2} - V$$

Vectors | Hypers

A metastable de Sitter example Fre, Trigiante & Van Proeyen '03

The only known pre-2013 examples considered N=2 supergravity with vector- and hypermultiplets, and proposed that following ingredients were necessary for a de Sitter vacuum: As reviewed by Dall'Agata this morning

- non-Abelian, non-compact gauge groups with a product structure
- Constant Fayet-Iliopoulos terms
- Electric and magnetic gaugings, like de Roo-Wagemans in *N=4*

Complicated - is there a simpler example?

Not that anyone had found, despite some effort.

Do we really need all this? Lausanne Group '12-'13

We took a different approach and asked the following question:

Can we find <u>the obstruction</u> to having a metastable de Sitter vacuum in the simplest N=2 supergravity with one vector- and one hypermultiplet?

The simplest model is defined as follows:

- An Abelian gauge group with no FI terms - no charged scalars.

A scalar potential needs at least one gauging, i.e. a charged scalar:

- A 4d quaternionic Kähler manifold with at least one isometry.

The most general such metric has been described by Przanowski and Tod, and is the quaternionic version of the Gibbons-Hawking hyperKähler metric.

Can we find a simple no-go theorem?

NO.

Can we find a simple no-go theorem?

We looked for a bound on the averaged mass eigenvalues, just like in the cases with only hypers and only vectors.

If this turned out to be negative, then we would know that there would be at least one unstable mode, based on some linear algebra arguments.

4x4

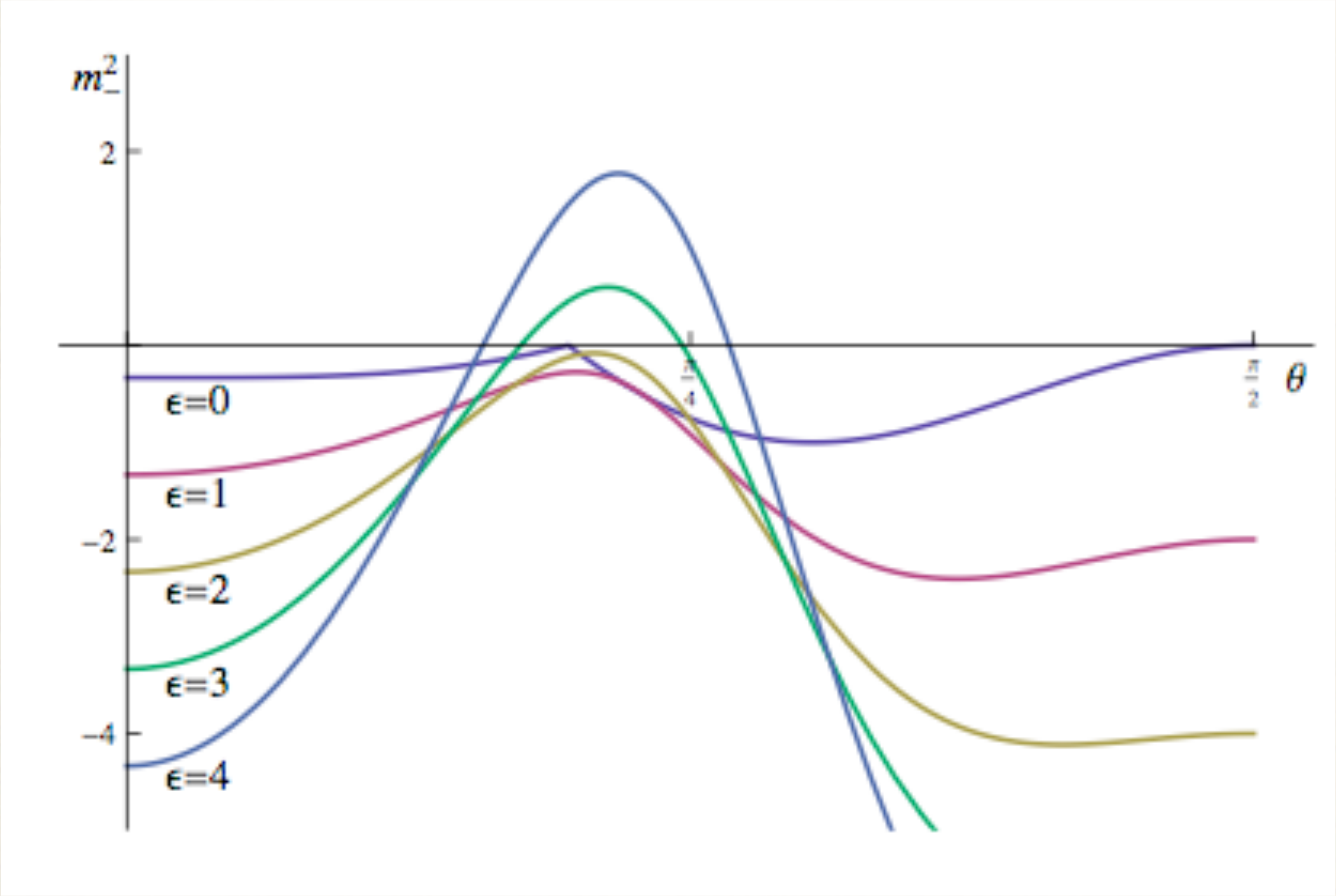
$$m_{ij}^2 \sim \begin{pmatrix} V_{u,v} & V_{u,\bar{z}} & V_{u,\bar{z}} \\ V_{z,v} & V_{z,\bar{z}} & V_{\bar{z},\bar{z}} \\ V_{z,v} & V_{z,z} & V_{z,\bar{z}} \end{pmatrix} \xrightarrow[]{\text{Trace submatrices}} m^2 \equiv \begin{pmatrix} m^2_{\rm hh} & m^2_{\rm hv} \\ m^2_{\rm hv} & m^2_{\rm vv} \end{pmatrix}$$

$$m^2_{\rm hh} \sim \delta^{uv} m^2_{uv}\,, \quad m^2_{\rm vv} \sim \delta^{\alpha\bar{\beta}} m^2_{\alpha\bar{\beta}}\,, \quad m^2_{\rm hv} \sim \sqrt{\delta^{\hat{u}\hat{v}}\delta^{\alpha\bar{\beta}} m^2_{\hat{u}\alpha} m^2_{\hat{v}\bar{\beta}}}$$

The two eigenvalues of m^2 represent an upper bound on the smallest mass eigenvalue and a lower bound on the largest mass eigenvalue of m^2_{ij}.

Bound on the smallest eigenvalue

Given the explicit quaternionic-Kähler metric we can directly compute the bound on the smallest eigenvalue m_-^2 which only depends on 2 quantities:



$$\epsilon = \frac{V}{m_{3/2}^2}$$

θ parametrizes the relative strength of supersymmetry breaking between the vector and hyper sectors

There is no obstruction to a metastable de Sitter vacuum if:

$$V > 2.17\ m_{3/2}^2$$

No no-go means go

We showed that there is no obstruction to having a metastable de Sitter in this model if the following two conditions hold:

- Both hyper and vector sectors must contribute to supersymmetry breaking, which is sensible given the no-go theorems.

- The cosmological constant is sufficiently large compared to the gravitino mass (in Planck units) - good for inflation $\epsilon \gg 1$, but not late times.

We then constructed examples by locally tuning the parameters in the model, i.e. the metric data, while respecting the special geometries.

Explicit examples of simple metastable de Sitter vacua in N=2 supergravity using just <u>curved</u> sigma-models and no additional ingredients.

Back to the old list of ingredients

- non-Abelian, non-compact gauge groups with a product structure ✗
- Constant Fayet-Iliopoulos terms ✗
- Electric and magnetic gaugings, like de Roo-Wagemans in N=4 ✗

None are required

Conclusions

- We have constructed new, simple examples of metastable de Sitter vacua in N=2 gauged supergravity with minimal matter content.
- This serves as a **proof of concept** - de Sitter vacua in N=2 supergravity do not require a complicated set of ingredients.
- We could do this as it was possible to directly study the full mass matrix, without needing to guess some special directions.
- We have now extended this analysis to the more general case i.e. n Abelian vectors and m hypers Catino, Scrucca & Smyth - coming soon.