Singlet-Stabilized Minimal Gauge Mediation

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1. Review & Motivation

2. Singlet-Stabilized Minimal Gauge Mediation

3. Stabilizing the Uplifted Vacuum
Review & Motivation

SUSY

Gauge Mediation

metastable SUSY

massive SQCD (ISS)

uplifted ISS
Supersymmetry

SUSY solves the Hierarchy Problem

1. How is SUSY-breaking transmitted to SSM?

2. How is SUSY broken?
Gravity Mediation: always there

\[ m_{\text{soft}} \sim \frac{F}{M^*_\text{pl}} \]

Problems:
- Flavor
- Calculability

Gauge Mediation
- Flavor universal soft masses
- Requires lower SUSY-breaking scale
- Often calculable
Gauge Mediation

- **Minimal Gauge Mediation**

  \[ W_{\text{eff}} = X\bar{\phi}\phi \quad \text{where} \quad \langle X \rangle = X + \theta^2 F \quad \Rightarrow \quad m_{\text{soft}} \sim \frac{\alpha F}{4\pi X} \]

- **Direct Gauge Mediation**
  - $G_{SM}$ embedded in flavor group of SUSY-breaking sector
  - Very compatible with ‘dynamical SUSY-breaking’ ideal!
How is SUSY broken?

- Want a model where $m_{\text{SUSY}} \ll M_{\text{pl}}$ is dynamically generated: Dynamical SUSY Breaking (DSB).

- Known example of small dynamical mass scale in nature: $\Lambda_{\text{QCD}}$ (due to logarithmic running of gauge coupling).
  $\Rightarrow$ Will probably need nonperturbative physics!

- **True SUSY very difficult!** (Witten Index Argument).
  - No SUSY-vacua $\rightarrow$ either chiral or contain massless matter
  - 3-2, 4-1, ITIY, . . .
  - Difficult to make into realistic DGM model
How about metastable SUSY?

Allowing the existence of SUSY-vacua removes many restrictions.

⇒ now just need to make sure that there is an uplifted local minimum of the potential.

Of course the false vacuum should have a lifetime longer than the age of the universe!
Another very good reason for metastable SUSY (apart from increased model building freedom/simplicity).

- Problem\(^1\): in Direct Gauge Mediation often get \(m_\lambda \ll m_\tilde{f}\)
- Little Hierarchy Problem!
- Can show that this is due to global vacuum structure of the theory.
- \(m_\lambda\) vanishes to LO in SUSY if we live in lowest-lying vacuum of the renormalizable theory (Komargodski, Shih 2009). (Making SUSY maximal does not help.)

\(\Rightarrow\) metastable SUSY!

---

\(^1\)first noticed by Izawa, Nomura, Tobe, Yanagida (1997)
Remark

It is useful to elaborate slightly on this.

Many models of dynamical SUSY breaking can be described by a generalized O’Raifeartaigh model at low energies.

Such a model always has a field that is undetermined at tree-level but gets a potential at 1-loop: **Pseudomodulus (PM)**.

If this model implements Direct Gauge Mediation, then messengers which are

- *tachyonic* for some values of the PM contribute to $m_\lambda$
- *stable everywhere* do not contribute to $m_\lambda$

![Diagram showing the difference between tachyonic and stable messengers in the context of SUSY breaking.](image)
Metastable SUSY Models

Some earlier models:
- Dine, Nelson, Nir, Shirman 1995
- Arkani-Hamed, March-Russell, Murayama 1997
- Luty, Terning 1998
- Banks 2005
- ...

Turns out metastable SUSY is generic!

Simplest example:
SUSY-QCD with small quark mass

(Intriligator, Seiberg, Shih 2006).
Start with $SU(N_c)$ SUSY-QCD with $N_f$ vector-like quarks:

<table>
<thead>
<tr>
<th></th>
<th>$SU(N_c)$</th>
<th>$SU(N_f)$</th>
<th>$SU(N_f)$</th>
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<th>$U(1)_R$</th>
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<td>1</td>
<td>$\frac{N_f - N_c}{N_c}$</td>
</tr>
<tr>
<td>$\bar{Q}$</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>$-1$</td>
</tr>
</tbody>
</table>

$N_f < 3N_c \rightarrow$ asymptotically free $\rightarrow$ strongly coupled for $E < \Lambda$

For $N_c + 1 \geq N_f \geq 3/2N_c$ the strongly coupled IR-physics is described by another SUSY-QCD which is IR-free

<table>
<thead>
<tr>
<th></th>
<th>$SU(N_f - N_c)$</th>
<th>$SU(N_f)$</th>
<th>$SU(N_f)$</th>
<th>$U(1)_B$</th>
<th>$U(1)_R$</th>
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<tbody>
<tr>
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<td>$\bar{q}$</td>
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<td>$\frac{N_c}{N_f - N_c}$</td>
</tr>
<tr>
<td>$\bar{q}$</td>
<td>$\bar{q}$</td>
<td></td>
<td>1</td>
<td></td>
<td>$-\frac{N_c}{N_f - N_c}$</td>
</tr>
<tr>
<td>$M$</td>
<td>1</td>
<td></td>
<td></td>
<td>0</td>
<td>2$\frac{N_f - N_c}{N_f}$</td>
</tr>
</tbody>
</table>

$W = \text{Tr} q \bar{M} q$
SUSY-QCD & Seiberg Duality

FREE ELECTRIC PHASE

- electric $SU(N_c)$
  - IR free

FREE MAGNETIC PHASE

- magnetic $SU(N_F-N_c)$
  - UV free

Coupling in IR gets stronger

Conformal window (same IR fix point)

$W_{\text{ADS}} = (N_c - N_F) \left[ \frac{\Lambda^{3N_c-N_F}}{\det M} \right]^{\frac{1}{N_c-N_F}}$

NO DUAL

Cornell University

David Curtin

Singlet-Stabilized Minimal Gauge Mediation
The ISS Model

Consider SQCD in free magnetic phase with small quark mass:

\[ SU(N_c) \text{ with } W = mQ\bar{Q} \Rightarrow SU(N_f)^2 \rightarrow SU(N_f) \]

where \( m \ll \Lambda \) (does not affect duality).

- magnetic theory: \( SU(N) \) with \( W = h\text{Tr}qM\bar{q} - h\mu^2\text{Tr}M \sim \Lambda m \)

(Define \( N = N_f - N_c \))

- Notice apparent \( R \)-symmetry \( R(q, \bar{q}, M) = 0, 0, 2 \)

- **SUSY-breaking** by rank condition: \( F_{Mj} = hq^i\bar{q}_j - h\mu^2\delta^i_j \)
  \[ \text{rank } N \leq \text{rank } N_f \geq 3N \]
Where is the SUSY-vacuum?

- We know this theory has a SUSY-minimum. Where is it in the magnetic description?

- Consider large meson VEVs: \( W = h \text{Tr} qM\bar{q} - h\mu^2 \text{Tr} M \)

- squarks get large mass \(\rightarrow\) integrate out
  \(\rightarrow\) pure SYM
  \(\rightarrow\) gaugino condensation
  \(\rightarrow\) SUSY minimum (nonperturbative SUSY-restoration!)

\[
q = \bar{q} = 0, \quad M = \Lambda_m \left( \frac{\mu}{\Lambda_m} \right)^{2N/(N_f-N)}
\]

- \(R\)-symmetry was accidental! It is weakly but explicitly broken by gauge anomaly \(\Rightarrow\) meta-stable SUSY-breaking!
“Semi-Dynamical” Meta-Stable SUSY-Breaking

ISS is not true dynamical meta-stable SUSY-breaking due to the small quark mass put in by hand.

However, its simplicity & non-perturbative mechanism make it an instructive model-building sand box!

Use it to build a model of Direct Gauge Mediation.
\[ \langle q\bar{q} \rangle = \begin{pmatrix} \mu^2 & N_{F-N} \\ 0 & 0 \end{pmatrix} \rightarrow SU(N) \times SU(N_f) \downarrow SU(N)_D \times SU(N_f-N) \]

- Decompose fields into representations of unbroken symmetries:

\[ M = \begin{pmatrix} N & N_{F-N} \\ V & Y \\ \bar{Y} & Z \end{pmatrix} \rightarrow q = \begin{pmatrix} \mu + \chi_1 \\ \rho_1 \end{pmatrix}, \quad \bar{q} = \begin{pmatrix} \mu + \bar{\chi}_1 \\ \bar{\rho}_1 \end{pmatrix} \]

Pseudomodulus: no potential at tree-level. Loop effects stabilize it at the origin \( \Rightarrow U(1)_R \) is unbroken!

Embed \( G_{SM} \) in \( SU(N_f - N) \): vectors could be messengers of DGM!
ISS Vacuum

 pseudomoduli space of ISS vacuum

 messengers stable everywhere

 Loop corrections stabilize pseudomodulus at origin
Problems

- Unbroken $R$-symmetry forbids gaugino masses (violations from NP effects too small) → must give the pseudomodulus $Z$ a VEV!

$$M = \begin{pmatrix} N & N_F-N \\ V & Y \\ Y & Z \end{pmatrix}^N_{N_F-N}$$

- Even if we break $R$-symmetry spontaneously the ISS vacuum is still the lowest-lying vacuum in the renormalizable theory → suppressed gaugino mass!

⇒ Need to break $R$-symmetry explicitly!
Deforming the ISS Model

There are many ways to break the magnetic $R$-symmetry \textit{spontaneously}, but to break it \textit{explicitly} we must add terms of the form

$$
\delta W_{el} \sim \frac{1}{\Lambda_{UV}} Q\bar{Q}Q\bar{Q} \quad \rightarrow \quad \delta W_{mag} \sim \epsilon \mu M^2 \quad \text{where} \quad \epsilon \sim \frac{\Lambda^2}{\mu \Lambda_{UV}} \ll 1
$$

This introduces new SUSY-vacua at $M \sim \mu / \epsilon$!

Good:
- Get gaugino mass at LO in SUSY

Bad:
- strong tension between reasonable $m_\lambda$ and lifetime of false vacuum
- deformation can be non-generic or contrived
In the ISS vacuum, $\langle q\bar{q} \rangle$ has maximum rank $N$.

Let’s expand around a configuration with fewer squark VEVs instead:

$$\text{rank} \langle q\bar{q} \rangle = k < N$$

At tree-level there will be tachyonic stuff but just run with it for now!

Different symmetry breaking pattern:

$$SU(N) \times SU(N_f) \times U(1)_R \times U(1)_B \rightarrow SU(N-k) \times SU(k) \times SU(N_f-k) \times U(1)' \times U(1)''$$
New Idea: Uplift the ISS Model

\[ M = \begin{pmatrix} k & N_F-k \\ V & Y \\ Y & Z \end{pmatrix} \]

\[ q = \begin{pmatrix} k & N_F-k \\ \mu + \chi_1 & \rho_1 \\ \chi_2 & \rho_2 \end{pmatrix} \]

\[ \overline{q} = \begin{pmatrix} k & N-k \\ \mu + \overline{\chi}_1 & \overline{\chi}_2 \\ \overline{\rho}_1 & \overline{\rho}_2 \end{pmatrix} \]

Direct Gauge Mediation: Embed \( G_{SM} \) in \( SU(N_f - k) \)

- flat at tree-level: pseudomodulus
- messengers stable everywhere: do not help with \( m_\lambda \)
- these messengers are tachyonic for \( |Z| < \mu \Rightarrow \) generate gaugino mass at LO!
ISS Vacuum

- **pseudomoduli space of ISS vacuum**
- **messengers stable everywhere**
- **Loop corrections stabilize pseudomodulus at origin**
Uplifted Vacuum

Fields roll towards the ISS vacuum!

pseudomoduli space of uplifted vacuum

messengers

tachyonic

stable

squarks
Shift meson VEV: everything is stable!
GKK Model (Giveon, Komargodski, Katz 2009)

- Magnetic theory: \( W = h \text{Tr} q_\bar{q} M \bar{q} - h \mu^2 \text{Tr} M \), \( M = \left( \begin{array}{ccc} V & Y \\ \bar{Y} & Z \end{array} \right) \)

- Need to give meson a VEV \( \langle Z \rangle > \mu \)

- Problem: in a renormalizable WZ model can’t have SUSY vacuum if one of the VEVs \( \gg \) mass scales in Lagrangian.

- Possible Solution: Split quark masses:

\[
\mu^2 \times 1 \rightarrow \begin{pmatrix} k & N_F-k \\ \mu_1 & \mu_2 \end{pmatrix}^k \quad \text{where} \quad \mu_1 \gg \mu_2
\]

- \( \rho_2, \bar{\rho}_2 \) messengers tachyonic for \( |Z| < \mu_2 \)

**Leaves possible window for SUSY minimum:** \( \mu_2 \ll |Z| \ll \mu_1 \)
To shift $Z$-VEV, again break $R$-symmetry explicitly by adding extremely finely tuned meson deformations

$$\delta W_{mag} = \epsilon_1 \mu_2 \text{Tr}(Z^2) + \epsilon_2 \mu_2 (\text{Tr}Z)^2$$

Good:
- It works! Get reasonable gaugino masses.
- Very important proof-of-principle!

Bad:
- Extremely contrived form of deformations
- Non-generic couplings
- Imposed mass hierarchies
- Requires enormous flavor symmetries, at least $SU(24)$
  $\Rightarrow$ Landau Pole of SM gauge couplings below $M_{GUT}$
Our Goals

We want to build new & improved ISS model!

- Needs to be uplifted to solve gaugino mass problem
- Want hidden sector to be minimal, i.e. $SU(5)$ flavor symmetry. This will avoid the Landau Pole.

Also would like minimal clutter (contrived deformations, nongeneric couplings).
Singlet-Stabilized
Minimal Gauge Mediation
Start Building Our Model

Choose Magnetic Gauge Group $SU(N)$

Possible number of squark VEVs: $\text{rank} \langle q\bar{q} \rangle = k = 0, 1, \ldots N$

⇒ make minimal choice $N = 1$

⇒ trivial magnetic gauge group

Only two pseudomoduli spaces: ISS ($k = 1$) and uplifted ($k = 0$)

Choose Flavor Group $SU(N_f)$

Want minimal hidden flavor group to avoid Landau Pole.

Uplifted ISS has unbroken flavor group $SU(N_f - k)$, with $k = 0$ here.

⇒ Choose $N_f = 5$. 

Start Building Our Model

Ansatz for magnetic theory: “$SU(1)_c \times SU(5)_f$"

\[ W = h\bar{\phi}_i M^i_j \phi^j - hf^2 M^i_j. \]

<table>
<thead>
<tr>
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<th>$SU(5)$</th>
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<th>$U(1)_R$</th>
</tr>
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<tbody>
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<tr>
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<td>0</td>
</tr>
<tr>
<td>$M$</td>
<td>Adj + 1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Identify $SU(5)$ flavor group with $G_{SM}$

Both these fundamentals will be tachyonic for small $|M|$ in the uplifted pseudomoduli space

$\Rightarrow$ **A Single Pair Of Minimal Gauge Mediation Messengers!**

**Need to stabilize the meson at nonzero VEV.**
Deform the model to generate an effective potential (tree + loop) which pushes the meson away from the origin.

**Meson Deformations:** \( \delta W_{\text{mag}} \sim \epsilon f M^2 \)?
From GKK we know this can’t work for our small flavor group.

**Baryon Deformations:** \( \delta W_{\text{el}} \sim \frac{1}{\Lambda_{\text{UV}}^2} Q^5 \rightarrow \delta W_{\text{mag}} \sim m_{\phi}\phi \)?
Only works for \( SU(7)_f \rightarrow SU(2)_f \times SU(5)_f \). Very non-renormalizable in electric theory.

**Add A Singlet Sector Coupled To The Meson!**
(Witten 1981; Dine & Mason 2006; Csaki, Shirman & Terning 2006)
Take an O’Raifeartaigh Model that SUSY. It will have a pseudomodulus $X$.

If there are no gauge interactions, the effective potential at 1-loop will look like

$$V_{\text{tree}} = M^4 \lambda^2 \quad \longrightarrow \quad V_{\text{eff}} = M^4 \lambda^2 \left[ 1 + b \frac{\lambda^2}{8\pi^2} \log \frac{|X|^2}{\Lambda^2} \right]$$

SUSY-breaking scale, tree contribtion, 1-loop contribution
This can be written as

\[ V_{\text{eff}} = M^4 \lambda(X)^2 \quad \text{where} \quad \lambda(X)^2 = \lambda^2 \left[ 1 + b \frac{\lambda^2}{8\pi^2} \log \frac{|X|^2}{\Lambda^2} \right] \]

Effective coupling \( \lambda \) increases with \( X \): consequence of RGE
\( \Rightarrow \) \( X \) is stabilized at the origin.

**Gauge Interactions** try to decrease \( \lambda \) for larger \( X \)
\( \Rightarrow \) can drive \( X \) away from the origin!
\[ W = h\bar{\phi}M\phi + (-hf^2 + dSS)\text{Tr}M + m'(SZ + ZS) \]

<table>
<thead>
<tr>
<th></th>
<th>(SU(5))</th>
<th>(U(1))</th>
<th>(U(1)_R)</th>
<th>(U(1)_S)</th>
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<td>0</td>
</tr>
<tr>
<td>(\bar{\phi}^j)</td>
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<td>0</td>
</tr>
<tr>
<td>(M)</td>
<td>\text{Adj + 1}</td>
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<tr>
<td>(Z)</td>
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<td>2</td>
<td>1</td>
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<tr>
<td>(\bar{Z})</td>
<td>1</td>
<td>0</td>
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<td>-1</td>
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<td>(S)</td>
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<td>1</td>
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<tr>
<td>(\bar{S})</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

For \(m'\) not too large, singlets get VEV

\(\rightarrow U(1)_S\) and \(U(1)_R\)

\(\rightarrow\) negative log contribution in 1-loop potential \(V_{CW}(M)\)

\(\Rightarrow \langle M \rangle \neq 0\) possible
Split up the meson $M$ into singlet and adjoint components

$$M = M_{\text{adj}} + M_{\text{sing}}$$

$M_{\text{sing}}$ is stabilized by the singlet sector

$$V_{CW}(M_{\text{sing}}) = V_{CW}^{\text{mess}} + V_{CW}^{\text{sing}}$$

drives towards region where messengers are tachyonic
drives away from region where messengers are tachyonic

What about the adjoint meson?

$$V_{CW}(M_{\text{adj}}) = V_{CW}^{\text{mess}}$$

TACHYONIC!
Fix the Adjoint Instability

How to stabilize the Adjoint Meson?

1. **Add Flavor Adjoint:** $\Delta W_{mag} = m_{adj} MK$
   $\rightarrow$ **Landau Pole**

2. **Couple to field with** $R = -2$ **that gets a VEV**
   $\Delta W_{mag} = MMA$
   $\rightarrow$ complicated & highly non-renormalizable in electric theory

3. **Meson Deformation:** $\Delta W_{mag} = m_{adj} \text{Tr} (M_{adj})^2$  \( (R) \)

Some simple Meson Deformations are very hard to avoid in uplifted ISS models!
Complete Model for SUSY Sector in SSMGM

Magnetic Theory below scale $\Lambda$:

Trivial Gauge Group, $SU(5)$ flavor symmetry:

$$ W = h\bar{\phi}_i M^i_j \phi^j + (-hf^2 + dS\bar{S})\text{Tr}M + m'(Z\bar{S} + S\bar{Z}) + m_{adj}\text{Tr}(M'^2) + a\frac{\det M}{\Lambda^2_m} $$

(Instanton Term restores SUSY for $M \sim \sqrt{f\Lambda}$)

Electric Theory above scale $\Lambda$:

augmented massive $SU(4)_c \times SU(5)_f$

$$ W = \left( \tilde{f} + \frac{\tilde{d}}{\Lambda_{UV}} S\bar{S} \right) Q\bar{Q} + m'(Z\bar{S} + S\bar{Z}) + \frac{\tilde{c}}{\Lambda_{UV}} \text{Tr}(Q\bar{Q})'^2 $$
Scales of Parameters

\[ W = h\bar{\phi}_i M^i_j \phi^j + (-hf^2 + dS\bar{S}) \text{Tr}M + m'(Z\bar{S} + S\bar{Z}) + m_{adj} \text{Tr}(M'^2) + a\frac{\det M}{\Lambda_m^2} \]

- \( m', f \ll \Lambda \) free parameters. Generally \( f \gtrsim 10m' \).

- \( \Lambda \lesssim \Lambda_{UV}/100 \) for calculability. But no minima for \( \Lambda \ll \Lambda_{UV}/100 \).

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>( \Lambda )</th>
<th>( \Lambda_{UV} )</th>
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<tbody>
<tr>
<td>Scenario 2</td>
<td>( 10^{16} )</td>
<td>( 10^{18} )</td>
</tr>
</tbody>
</table>

- \( h \sim 1 \) unknown.

- Typical size of \( d \sim \frac{\Lambda}{\Lambda_{UV}} \sim 0.01 \), \( m_{adj} \sim d\Lambda \).

Is tiny \( d \ll h \sim 1 \) problematic for analysis at 1-loop? NO!
Vacuum Structure without Instanton Term

quantum corrections stabilize PM here

right near the origin messengers are tachyonic
Effect of Instanton Term

Creates SUSY-minimum at $M_{\text{sing}} \sim \sqrt{\Lambda f}$
Effective Potential Along Pseudomoduli Space

\[ V_{\text{tot}}/m'^{4} - \text{const} \]

Meson stabilized at \( \langle M_{\text{sing}} \rangle = O(1) \times \sqrt{h/d} f \)

to ISS vacuum

to SUSY vacuum
Direct Gauge Mediation

Gauge $SU(5)$ flavor symmetry and identify with $G_{SM}$.

$$W_{eff} = X \bar{\phi} \phi \quad \text{where} \quad X = \frac{h}{\sqrt{N_f}} M_{sing} \quad \Rightarrow \quad m_{soft} \sim \frac{\alpha}{4\pi} \frac{F}{X}$$

Important parameter for scales is $r = \sqrt{N_f h d^f m'} > 1$.

\[ m_{PM} \quad \overset{1 < r \lesssim 10}{\leftrightarrow} \quad m_{soft} \quad \overset{m_1}{\text{m}} \quad f \quad X \quad m_{adj} \quad \Lambda \quad \Lambda_{uv} \quad \text{Scenario 1 or 2} \quad \text{Log}_{10} \frac{M}{GeV} \]

\[ m_{R} \quad \text{m} \quad [r \leq 10] \]

\[ \boxed{\text{NO LANDAU POLE !!}} \]
Stabilizing the Uplifted Vacuum
We need to understand the stabilization in detail

Why bother? We know that it’s possible to get minima in the effective potential along the pseudomoduli space.

- Need to understand whether existence of minima is generic or tuned
  → If tuned, what conditions must be satisfied by the UV completion to make it generic?

- We have $d \ll h$, so how do we know we can trust our 1-loop calculation?
Effective Potential Along Uplifted Pseudomoduli Space

\[ V_{\text{eff}} = V_{\text{tree}} + V_{\text{CW}} \]

\[ V_{\text{tree}} = \text{const} - c \frac{m'^2}{\Lambda} M^4_{\text{sing}} \]

\[ V_{\text{CW}} = \frac{1}{64\pi^2} \text{STR} m^4 \log \frac{m^2}{\Lambda^2} \]

(masses depend on \( M_{\text{sing}} \leftrightarrow \text{pseudomodulus} \))
1-Loop Contribution

Messengers

Singlet masses depending on $g$

Singlet masses NOT depending on $g$

\[ V_{CW} = \text{const} + \frac{1}{8\pi} (1 - t) \log M_{\text{sing}} + \frac{1}{x} \text{stuff} \]
\[ V_{CW} = \frac{1}{8\pi} (1 - t) \log M_{\text{sing}} + \frac{1}{X} \text{stuff} + \text{const} \]
We find that \( \frac{1}{2} \lesssim t \lesssim 1 \) is required for minimum:

\[
\frac{m'}{f} = 2g\sqrt{N_f} \frac{d}{h} \left( 1 - \frac{d^2 N_f}{h^2} \frac{1}{2} t \right)
\]

\[\Rightarrow 10^{-4} \text{ tuning!}\]

- Typical for such models.
- Ideally explain with UV completion. (This is rather optimistic. . . )
Can We Trust 1-Loop calculation?

**Messengers**

- $h >> a$
- Two-loop correction

(positive log)

**Singlet masses depending on g**

- $g >> a$
- Two-loop correction

(negative log)

**Singlet masses NOT depending on g**

- "1/x" stuff

(positive log)

"Large" 2-loop corrections do NOT affect part of Vcw that generates local minimum
Conclusions
Conclusions

- ISS models are an extremely simple example of non-perturbative meta-stable SUSY-breaking.

Problems:
- Many Direct Gauge Mediation Models have Landau Poles.
- Uplifted ISS models avoid tiny gaugino masses but are difficult to stabilize.

We proposed Singlet-Stabilized Minimal Gauge Mediation: a ‘minimal’ uplifted ISS model with $SU(5)$ flavor symmetry. ⇒ No Landau Pole, No Gaugino Mass Problem.

Lots of work to be done to address the origin of smaller mass scales (ISS) and problems with tuning & UV completion (SSMGM).