KEY PARTS OF: INTRALUGAR, SERS, SNU: SUSY, R/M, METASTABLE VIC.

THIS DRAW HEAVY FROM INTRALUGAR 7 SERS, SUSY DEC. SEE ALSO DINE'S
CARGESESE LECTURES FOR A BRIEF SUMMAR.

THE MAIN IDEA IS EASY TO SUMMARIZE:
SUSY, M. VIC. → NON-GENERIC
METASTABLE SUSY, M. VIC. → GENERIC

SINCE SUSY HAS N. SUSY. VA. IT WAS PREVIOUSLY NOT V.IABLE FOR SUSY, M.
EVEN THOUGH IT HAD THE BENEFIT OF DSB SCALE GENERATION. ON
OWNING A SIMPLE SUSY SUSY MODEL TO SOLO WE CAN HAVE DSB E
COST OF METASTABILITY.

ISS WORKS IN A TREE-LEVEL SUSY, M. MODEL WHICH IS DUAL TO AN
ELECTRIC SUSY SUSY THEORY.

INTRODUCTORY REMARKS

- ACCEPT METASTABILITY FROM THE START.
- "NO SUSY VA.\) CONSTRAINTS HOLE OUTF
- ALLU MONT LAUS W/ NON-ZERO UNSEEN INDEX, NO U(1)R.
- STILL REG. COUNTING (can be hidden in W-VAC.
- \[ \varepsilon = \frac{1}{\lambda} \frac{\lambda}{\sqrt{V}} \]
- VIABILITY DEPENDS ON PARAMETRICALLY LARGE RIDE
- OLD MODELS OF SUSY: SCAFFOLLE WHEN VA. E LARGE FIELDS
- ISS MODEL: VA. @ SMALL EXPECTATION VALUES
- FIX \( \lambda \), \( \varepsilon \rightarrow \infty \): SUS. UNSCAFFALED @ UE VA. NOT SPECIFIC.
- LAMINAR POT OF LIGHT MODES SMOOTH, VA. E SMALL BUT DECO EV.
- \( \varepsilon \) CAN'T CONTROL DECO EV. BUT CAN STILL GET A LOT OF VA.

MAIN EXAMPLE (HOMOCHARGE REG. AS 'ISS MODEL')

\( n = 1 \) SQCD WITH \( (N+1) \) F < \( \frac{3}{4} H \) F, FIFTH RANK CONTINUED IN UP
12 T H W/ SCF. SUSY @ TREE LEVEL BY RANK CONDITION
\( (\text{e}^2 \text{P.26 fg}) \)

UV T H: CIV POT IS NOT IP ANGULAR. LOW E EFF POT IS ORBITAL ON
INCLUDING UV EFFECTS.
2. THE MACRO MODEL, PART I

CHIRAL SE: \[ W = h \text{Tr} \, \tilde{q} \tilde{c} \tilde{c} - h \eta^2 \text{Tr} \, \tilde{q} \tilde{c} \]

\[ W = h \eta^2 \tilde{q} \tilde{c} \tilde{c} - h \eta^2 \tilde{q} \tilde{c} \tilde{c} \]

\[ K = \text{Tr} \, \tilde{q} \tilde{q} + \text{Tr} \, \tilde{q} \tilde{q} + \text{Tr} \, \tilde{q} \tilde{q} \]

\[ = K_{\text{con}} \]

NOTE: \[ W = h \text{Tr} \, \tilde{q} \tilde{c} \tilde{c} - h \eta^2 \text{Tr} \, \tilde{q} \tilde{c} \]

\[ \text{MOST GENERAL} \]

\[ W \text{ ON SYST.} \rightarrow SU(N) \times SU(N) \]

\[ \text{BECOMES GLOBAL SYM} \rightarrow SU(N) \times SU(N) \]

\[ U(1) \times U(1) \]

\[ U(1) \times U(1) \]

\[ \text{F} > N \Rightarrow \text{F-TEENS CANNOT ALL BE SET TO ZERO} \]

\[ \text{SUPPLY RANK CONDITION} \]

\[ \text{CLASSICAL HÖNNL SPACE} \text{ (UP TO SYMMETRY)} \]

\[ \Phi = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ \Phi = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ \Phi^T = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ V_{\text{vac}} = (F-N) |h^2 \tilde{q} \tilde{q}| \]

VACUUM THAT PRESERVES UNBROKEN FLAVOR RGT (MAX UNBROKEN GLOBAL SYM)

\[ \Phi_0 = 0 \]

\[ \Phi_0 = 0 \]

\[ \tilde{q} = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ (2.7) \]

EXPAND ABOUT THIS VACUUM TO IDENTIFY LIGHT FIELDS

\[ \Phi = \left( \begin{array}{c} \delta \gamma \\ \delta \delta^T \\ \delta \delta \end{array} \right) \]

\[ \Phi = \left( \begin{array}{c} \delta \gamma \\ \delta \delta^T \\ \delta \delta \end{array} \right) \]

\[ \tilde{q} = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ \tilde{q}^T = \left( \begin{array}{c} \gamma_0 \\ \gamma_1 \\ \vdots \\ \gamma_{F-N} \end{array} \right) \]

\[ \text{THIS JUST DEFINES A SET OF FIELDS WITH SIMPLIFIED NAMES.} \]
WE WANT TO SEE HOW W GIVES TREE-LEVEL MASSES TO THESE FIELDS.

CLAIM:
1. NOT ALL FIELDS GET MASSES \( \sim |W| \)
2. GOLDSTONE BOSONS OF BROKEN GLOBAL SYM. (MASSLESS)
   \[
   \left( \begin{array}{c}
   \zeta - \lambda \frac{i}{m} S \frac{S}{m} \\
   \mu \frac{S}{m} S \frac{S}{m}
   \end{array} \right), \quad \Re \left( \frac{k^+}{m} S \frac{S}{m} \right), \quad \Im \left( \frac{k^+}{m} S \frac{S}{m} \right)
   \]
   \[\text{SU(2)} \times \text{SU(2)} \times \text{SU(2)} \times \text{SU(2)} \times \text{SU}(2)
   \]
3. MASSLESS SCALARS ASSOCIATED WITH GAUGE FIELDS PLAT DI: \( \phi \)
   \[\phi \frac{S}{m} \quad \phi \frac{S}{m} = \left( \frac{k^+}{m} S \frac{S}{m} + \text{H.c.} \right)\]

COMMENTS (like a 'proof' but w/o proof):

WE CAN SHOW HEURISTICALLY THAT THE OTHER FIELDS GET TREE-LEVEL MASSES.

\[
W = \hbar \partial i c \phi_i \phi^i c - \hbar \partial i c \phi_i \phi^i c \]

\[\frac{2W}{\partial^2 \phi_i} = \hbar \phi_i \phi^i c - \hbar \phi_i \phi^i c\]

\[\frac{2W}{\partial^2 \phi_i} = \hbar \left( \phi_i \phi^i c - \hbar \phi i \phi^i \right)\]

\[V = \left| W_{\phi} \right|^2 + \left| W_{\phi} \right|^2 + \left| W_{\phi} \right|^2
\]

\[\frac{V}{4} \text{ where we now have } \left| W_{\phi} \right|^2 = \frac{1}{2} \left( \frac{2W}{\partial \phi} \right) \left( \frac{2W}{\partial \phi} \right)^\dagger = \text{Tr} \left( \frac{2W}{\partial \phi} \right)^2\]

THE FACTOR OF \( |W| \) IS COMMON TO ALL TERMS, SET TO 1 FOR NOW.
WE CAN WRITE IN MATRIX NOTATION (IMPLICIT \( \phi \phi \) AS \( \phi \phi \) ABS.);

\[V = |\phi \phi|^2 + |\phi \phi|^2 - |\phi \phi|^2 - |\phi \phi|^2\]

\[|\phi \phi|^2 = \frac{1}{2} \text{ Im} \left( \phi \phi \right) \frac{1}{2} \text{ Re} \left( \phi \phi \right)\]

\[\phi \phi = \left( \begin{array}{c}
   S \left( \mu + \frac{1}{m} \left( S \frac{S}{m} - \phi \frac{S}{m} \right) \right) + \frac{1}{2} \left( \phi \phi \right) \frac{1}{2} \\
   S \left( \mu + \frac{1}{m} \left( S \frac{S}{m} - \phi \frac{S}{m} \right) \right) + \frac{1}{2} \left( \phi \phi \right) \frac{1}{2}
   \end{array} \right)\]

\[|\phi \phi|^2 = |\mu|^2 S \frac{S}{m} S \frac{S}{m} + |\frac{1}{2} \left( \phi \phi \right) \frac{1}{2}|^2\]

In fact, the model is much simpler if we only look at mass terms. Ignore such constant, quartic + cusp LLAGO couplings.
Now consider the \((\phi^2 - \mu^2)\) term

\[
\phi^2 - \mu^2 = \left( \frac{1}{3} (s_{2x} + s_{2y}) (s_{2x} - s_{2y}) \right) \left( \frac{1}{3} (s_{2x} + s_{2y}) (s_{2x} - s_{2y}) \right)
\]

\[
= \left( \frac{1}{3} a_{+}^2 + \frac{1}{3} a_{-}^2 \right) \left( \frac{1}{3} a_{+}^2 + \frac{1}{3} a_{-}^2 \right)
\]

This is usually looking... let's simplify

\[
\begin{pmatrix}
A & B \\
C & D
\end{pmatrix}
\begin{pmatrix}
A^+ & C^+ \\
B^+ & D^+
\end{pmatrix}
= 
\begin{pmatrix}
AA^+ + BB^+ \\
CC^+ + DD^+
\end{pmatrix}
\]

We only care about doing something for the trace \((\text{Tr} \text{ implied})\)

\[
\text{Tr} \left| \phi^2 - \mu^2 \right|_{\text{mass}}^2 = \frac{1}{2} \left| 1 \right| (s_{2x} - s_{2y}) \left( s_{2x} - s_{2y} \right)^* \left| 1 \right|^2
\]

\[
\frac{1}{2} \left| (s_{2x} + s_{2y}) (s_{2x} - s_{2y}) \right|^2
\]

\[
= \frac{1}{2} \left[ (s_{2x} + s_{2y}) (s_{2x} - s_{2y}) \right]^2
\]

\[
= \frac{1}{2} \left( s_{2x}^2 + s_{2y}^2 \right)^2
\]

Still looks ugly, exp since \(s_{2x} \) goes in as \(1^2 \left| (s_{2x} + s_{2y}) \right|^2 \) but this is easy to fix, as hinted by the paper. Absorb \( s_{2x} \) into \( s_{2y} \):

\[
s_{2x} \to \frac{s_{2x}}{1 + |s_{2x}|}
\]

\[
|\frac{s_{2x}}{1 + |s_{2x}|} = \frac{1}{1 + |s_{2x}|}
\]

Now split \(s_{2x}\) into \(\text{Re} + i \text{Im}\) parts. (As a matter of)

\[
s_{2x} = a_+ + ib_+
\]

\[
2 \text{Tr} \left| \phi^2 - \mu^2 \right|_{\text{mass}}^2 = \frac{1}{2} \left[ (a_+ + ib_+) (a_+ + ib_+) \right]^2
\]

\[
= \frac{1}{2} \left( a_+^2 + b_+^2 \right) + 2 \left| a_+ b_+ \right|^2
\]

\[
= 2 \left( b_+^2 + a_+^2 \right) + 2 \left| a_+ b_+ \right|^2
\]

\[
= 2 \left( a_+^2 + b_+^2 \right) - 2 \left( a_+^2 + b_+^2 \right)
\]

\[
= 4a_+^2 - 4b_+^2
\]

\[
= 4 \left| \text{Im} (s_{2x}) \right|^2 + 4 \left| \text{Re} (s_{2x}) \right|^2
\]

\[
\left| \phi^2 - \mu^2 \right|_{\text{mass}}^2 = \left| 4 \left| \text{Im} (s_{2x}) \right|^2 + 4 \left| \text{Re} (s_{2x}) \right|^2 \right|
\]

\[
\left| \phi^2 - \mu^2 \right|_{\text{mass}}^2 = \left| 1 \left| \text{Im} (s_{2x}) \right|^2 + 1 \left| \text{Re} (s_{2x}) \right|^2 \right|^2
\]

So we see: \(\text{Tr}, \text{Re}, \text{Im}, \text{Im} (s_{2x}), \text{Re} (s_{2x})\) all get tree level masses.

So we've seen that the fields that are massive are indeed those that is what meant: mostly.

What remains to figure out: identify fields bosic, \(\pi, \mu, \eta\), flat directions.
Consider the 1-loop effective potential in $\bar{g}$ of $\{\phi_0, \phi_\pm, \phi_\mp = \pm i \phi_\pm\}$

$$V^{(i)} = \left[ \hbar^2 \lambda^2 \left( \frac{1}{2} a \text{Tr} S^2 + b \text{Tr} S^0 + b \text{Tr} S^\pm + b \text{Tr} S^- \right) \right] + \ldots$$

**NUMERICAL COEFFICIENTS**

This form comes from global symmetries of the potential.

I don't quite understand the statement underneath it. It says this is equivalent to saying that only planar diagrams contribute, e.g., (see below).

**PUTTING IN CLASSICAL MASSES** (This is done in Appendix B, p. 155)

- $a = \frac{\log 2 - 1}{8 \pi^2} (F - N)$
- $b = \frac{\log 4 - 1}{8 \pi^2} N$

**LET'S TRY TO SPEECH WHAT'S GOING ON**:

$$V^{(i)} = \frac{1}{\Lambda^2} \left( \text{Tr} M^\pm - \text{Tr} M_0 \right)$$

Treat $\text{Tr} M_0$ as classical $g_0$ (3-d space, labelled by $x_\mu, \theta$)

$$\Phi = \left( \begin{array}{c} \phi_0 \\ \phi_+ \\ \phi_- \end{array} \right) \quad \theta = \left( \begin{array}{c} \theta_0 \\ \theta_+ \\ \theta_- \end{array} \right)$$

The apparatus yields:

$$\langle V^{(i)} \rangle = \text{const} + \left( \frac{1}{2} g_0^2 \left( \sum_{i=1}^{n} x_i^2 \right) \right)^2 + b(F - N) \left( x_0 \right) + \ldots$$

**CLASSICAL MASSES**:

- Put $\phi_0, \phi_\pm, \phi_\mp$ into classical superpotential

$$W = \hbar \text{Tr} \left[ U + \Phi' \Phi - \hbar^2 \text{Tr} \right]$$

$$W = \hbar \text{Tr} \left[ e^{\lambda \Phi} \text{Tr} \Phi' \Phi + e^{-\lambda \Phi} \text{Tr} \Phi' \Phi + e^{\lambda \Phi} \text{Tr} \Phi' \Phi + e^{-\lambda \Phi} \text{Tr} \Phi' \Phi + e^{\lambda \Phi} \text{Tr} \Phi' \Phi - e^{-\lambda \Phi} \text{Tr} \Phi' \Phi + \text{...} \right]$$

**OBSERVE**:

- Off-diagonal components of $\Phi'$ do not contribute
- $\Phi, \Phi', \Phi''$ only couple to $\Phi_0$ fields $\Phi, \Phi'$ through cubic or higher ints.
- Mass matrix for these fields will be subtrice

**REMAINS TERMS**

$$W = \hbar \sum_{i=1}^{n} \left[ \left( x_i \phi_0 + \phi_0 \phi_i \right) \phi_i + \phi_0 \phi_i \phi_j \phi_i + e^{\lambda \Phi} \left( \phi_i \phi_j \phi_i \right) \phi_i - e^{-\lambda \Phi} \left( \phi_i \phi_j \phi_i \right) \phi_i \right]$$

This is just $(F - N)$ copies of the form

$$W_{\text{sub}} = \hbar \left( x_0 \phi_0 + \phi_0 \phi_0 + \phi_0 \phi_0 \phi_0 - x_0 \phi_0 \right)$$

This calculation has been done. (See Appendix A, p. 155) It gives a calculation for $\langle V^{(i)} \rangle$. This gives values for $a, b$ above.

**THE SUPERSTANDARD ABOVE SHOULD GIVE $V^{(i)}$ AT THE TOP OF THE PAGE**

But I'm too damn tired to check.
THE POINT IS THIS: $|\lambda| > 0$.

$\Rightarrow$ THE VACUA ARE STABLE, NO TACHYONIC DIRECTIONS.

SPECTRUM HAS HIERARCHY DICTATED BY MARGINAL IRRELEVANT COUPLING $\kappa$

- FIELDS WITH MASSES $\sim |\lambda|$
- PSEUDO NINJAS $\sim |\lambda| / V_{eff}$ FROM $V_{eff}$
- GOLDSTONES OF BROKEN GLOBAL SUSY REMAIN MASSLESS
- Goldstino is Massless

WORLD MODEL II: DYNAMICAL SUSY RESTORATION

GAUGE $SU(N)$; FOCUS ON $F > 2N$ (IR FEEDER)

$\lambda$ IS STRONGLY COUPLED FOR $E \gg \lambda$

$e^{-\frac{|\eta|^2}{\lambda^2} + i\eta} = \left( \frac{\lambda}{\lambda^2} \right)^{(F-3N)/2}$ VACUUM $\eta = 0$ (BARE $\lambda$)

$V_D = \frac{1}{2} \sum_p (Tr(T^p_h + T^p_q - Tr(T^p_h + T^p_q))$ VACUUM

$\Rightarrow 0$, TRIVIAL VACUUM.

SUSY IS COMPLETELY HIGGSED IN THIS VAC.

SUSY BURNING MECHANISM: SUSY GUAGE FIELDS GET MASS $\lambda$

- GOLDSTONES ($\lambda^* h^*_R / |\lambda|$) EXCEPT TO SUSY PSEUDO NINJAS
- PSEUDO NINJAS ($\lambda^* h^*_R / |\lambda|$) GET MASS $\lambda$

$\Rightarrow h^*_R, T^p_R$ REMAIN AS MASSLESS NONNINJAS.

NEXT STEP: COMPUTE $V_{eff}$ FOR PSEUDO NINJAS, DETERMINE IF THE PSEUDO ARE STABILIZED BEFORE ADDITIONAL WORK NEEDED! EFFECTS OF SUCH GUAGE FIELDS DROP OUT TO VACUUM $\theta$ IN $V_{eff}$ BUT FOR PSEUDO NINJAS.

WHY? TREE LEVEL SPECTRUM OF MASSIVE $SU(N)$ GUAGE FIELDS DO NOT DIRECTLY COUPLE TO SUSY VACUUM! D-TERMS VARY ON PSEUDO SPACE VERSUS $v_F$ FOR SUCH MASSIVE FIELDS, BUT DO NOT COUPLE DIRECTLY TO ANY NONZERO D-TERMS.

THE NET EFFECT OF BRACING $SU(N)$: CONVERTS SUSY VACUA.

WE ALREADY EXPECT THIS (SUSY VACUUM IN SUSY VACUA), BUT TO SEE IT:

$V = \text{Tr} (\eta + \eta^*) - \lambda^2 \eta^2 \Rightarrow \eta^* \eta^0$ GET MASS $\langle \lambda^2 \rangle$, CAN NOT DROP OUT

$w = \text{Tr} (\eta + \eta^*)$ IS SUSY VAC.

$e^{\frac{1}{2} \beta^* + 2} = \frac{\lambda^2}{(N C)} \Rightarrow \text{Tr} (\eta + \eta^*) = N \left( \frac{\lambda^2}{(N C)} \right)^{1/2}$

NOT: WE ARE NOT INCLUDING PLUGS FROM $V_{eff}$ AT ALL $\lambda^2$, THIS SCALE DEPENDS FROM EXPRESSING $\beta$ IN THE 14 DIMENSIONAL COUPLING.
(Continuing: see the SUSY vacua)

\[ \langle H^2 \rangle = \Lambda \exp \left( -\frac{2N}{F_N} \right) \exp \left( \frac{1}{F_N} \sqrt{F_N} \right) \Rightarrow \Rightarrow \rangle \Rightarrow \]

For \( |e| \ll 1 \), \( |H| \ll |\Lambda| \).

We have vacuum state \( \langle H^2 \rangle \ll |\Lambda| \).

So we see "Dynamical SUSY Restoration" in a tree-level SUSY model.

- For \( \Lambda \to 0 \), \( |H| \) fixed, the SUSY breaks.
- For \( \Lambda \) large but finite (small non-zero \( |H| \))
  - SUSY vacua come in from 0.
  - In SUS we have metastable SUSY vacua dynamically.

**Connection between SUSY & R-Sym.**

Macro TH1: \( U(1) \) is SUSY.

Macro TH2: \( U(1) \) breaks to \( U(1) \) (magnetic under SUSY gauge group).

\( \Rightarrow 3 \) SUSY vacua.

For \( \langle H \rangle \) near origin, \( U(1) \) is IR free.

\( \Rightarrow U(1) \) returns as accidental R-Sym of IR theory.

For SUSY near origin \( \Leftrightarrow \) accidental R-Sym.

**Effects from the underlying Macro TH1.**

Q: Do our results depend on physics at UV cutoff scale \( |\Lambda| \)?

We don't have any control of that physics.

Our only useful parameter is \( |e| \), can assume

\[ |e| = \left| \frac{1}{\Lambda} \right| \ll 1 \]

Claim: This guarantees that our couplings give dominant effect to low energy eff TH.

\[ \Leftrightarrow \Rightarrow \]
Loops from Hennings Lil

These show up as corrections to effective Kahler Pst:

\[ SK = \frac{c}{|\lambda|^2} \text{Tr} (\hat{\beta} + \hat{\beta}^2) + \ldots \]

(\[ c \text{ is positive.} \quad G(1) \]

**Main Argument:**

Decompact: Hi-Dim ops. suppressed by powers of \(|\lambda|\)

\[ \text{Hence do not affect low-E}. \]

**What We Did:**

We looked at low-E eff Pst \( \psi^0 \) of SUGRA flat dir.

We focused on light fields \( w \) mass \( \sim \lambda \) (say \( h = 1 \))

We neglected \( w \) mass \( \sim |\lambda|^2 \)

These heavy modes have masses also split by SUSYing.

Could this change our conclusion about decompact or eff Pst?

\[ \psi^0 \text{ from } \psi^1 \text{ is proportional to } |\psi^0| \]

\[ \Rightarrow \text{Not real analytic in } |\psi|^2 \text{ parameter of superpotential} \]

**Why?**

The modes we integrated out become massless as \( \lambda \to 0 \),

so contribution to eff Pst is singular there.

On the other hand: corrections from heavier modes \( \sim |\lambda|^2 \)

are necessarily real analytic in \( |\psi|^2 \).

\[ \Rightarrow \text{leading correction from microthy to pseudomodulus mass} \]

\[ \text{must have coefficient} \]

\[ \frac{|\lambda|^2}{|\lambda|^2} = |\lambda|^2 e^2 \ll |\lambda|^2 \]

\[ \Rightarrow \text{This is not analytic since it is differentiable } 0. \]

The \( \& \) smaller than low-E modes from thy contributions.

Why? Int cut massless modes for \( \lambda = 0 \) & simplify to \( SK \)

use this corrected \( k \).

\( w \) tree-level \( w \) to find eff on pseudo-flat directions. These corrections are \( \sim |\lambda|^2 e^2 \).

And are negligible.

This makes:

- WIG details of microthy, cannot determine \( \text{vev} \) effects
- For \( \sim |\lambda|^2 \) modes, cannot even determine sign
- Of \( \lambda \) like \( \lambda \), in \( SK \) cannot determine if they stabilize/pseudo-stabilize pseudo-flat directions

This is good that they cannot spoil the stabilization of the microthy, 1-loop effects

This boils down to an obvious discussion of the "irrelevanse of irrelevant operators."
Now reflecting non-trivial: in gauges, macro model we took into account non-perturbative effects in W{k}. These effects are also
suppressed by \( \Lambda_m \).

1. Why is this non-perturbable interaction relevant computed
even though it depends on \( \Lambda_m \)?

2. Why is it justified to neglect other terms in \( W_k \)
which are also suppressed by powers of \( \Lambda_m \)?

\( \Lambda_m \) appears in \( W_k \) as a way to parameterize the IR-ref
gauge coupling \( g_\text{IR} \) scales below \( \Lambda_m \).

This is conceptually different from \( \Lambda_m \) in \( W_k \) which
manifestation has to do with effects from the microscopically
ie phases above \( \Lambda_m \) pole scale.

In other words, \( W_k \) is generated by low-\( E \) physics.

Check: \( (\phi, \phi) \rightarrow (\phi, \phi) \approx \Lambda_m \rightarrow \text{leading calc.} \)

2.

Vending contribution to \( \delta k \sim \left| \frac{1}{\Lambda_m} \right| \), corresponding to

\[ \Delta W_{\text{Eff}} \sim \left| \frac{1}{\Lambda_m} \right|^2 \sim \left| \Lambda_m \right|^2 \]

for \( \left| e \right| \ll 1 \). \( \Delta W_{\text{Eff}} \sim \left| V_{ij} \right|^2 \) from macro thy.

Higher corrections to \( k \) have more \( \left( \phi / \Lambda_m \right) \) suppression
\( \rightarrow \text{negligible for} \left| \phi \right| \ll \Lambda_m \).

\( \text{From} \left| e \right| \ll 1 \rightarrow \left| h \right| \ll \left( \phi / \Lambda_m \right) \left( \text{PGO} \right) \)

Compare \( \Delta W_{\text{Eff}} \) to \( \Delta W_{\text{Eff}} \), correction from \( W_{\text{kin}} \) in macro.

\[ \Delta W_{\text{Eff}} \sim \left| \frac{e h_{\text{PGO}}}{\Lambda_m} \right| \]

For \( \left| \phi \right| \gg \left| \Lambda_m \right| e^\text{PGO} \), \( \Delta W_{\text{Eff}} \) is more important.

For smaller values of \( \phi \), both are negligible.

Conclusion: corrections from \( W_{\text{kin}} \) \& macro modes \( \approx \Lambda_m \)
do not invalidate our conclusions.

Macro models are "indeed control"
\& give dominant contributions to low-\( E \) dynamics.
METASTABLE VACUA IN SO(0)

Now we assemble all these tools & put them to use.

MODEL: SU(N) SO(0) w/ some \( A, F \) quarkes

\[
W = Tr \cdot mM \quad \text{v. non-degenerate}
\]

in such ground states:

\[
\langle M \rangle = (\lambda^{N-F} \det m)^{1 \over N} {1 \over m}
\]

\[
\Rightarrow \langle R \rangle = \langle \delta \rangle = 0
\]

CASE OF INTEREST: \( m_i \) small, same order of magnitude

\[
m_i \ll m_j \quad ; \quad \frac{m_i}{m_j} \sim 1
\]

Consider: \( F > N \); in this limit \( m_i \to 0, m_j/m_i \sim 1 \); 

\[
\langle M \rangle \to 0
\]

Can study this model in this limit w/ Seiberg duality:

MAGNETIC THY: SU(F-N) w/ scale \( \bar{\Lambda} \), \( F^2 \) singlets \( M_i \) & F meson quarkes \( \delta, \bar{\delta} \)

free magnetic range \( F < {2 \over 3} N \), max thm 1R field

\[
\Rightarrow \text{metric for moduli space smooth around origin}
\]

\[
K = {1 \over 2} Tr (\delta \delta + \bar{\delta} \bar{\delta}) + \frac{1}{4!\Lambda^2} Tr \cdot M^4 M + ...
\]

\[
\delta, \bar{\delta} > 0, R
\]

\[
\frac{1}{\lambda} \sim 1
\]

Prescribe values cannot easily be degenerate

(not associated w/ holomorphic info)

but qualitative results will not depend on this.

\[
W_{\text{phys}} = {1 \over \bar{\Lambda}} Tr \cdot \tilde{M} \tilde{\delta} + Tr \cdot mM
\]

\[
\lambda^{N-F} \lambda_{F-N} F = (-)^{F-N} \lambda^F
\]

\[
\bar{\Lambda}, \lambda \text{ not uniquely det by electric theory (not know of in mag theoy)}
\]

\[
\text{related to freedom to rescale } \delta, \bar{\delta}
\]

\[
\text{N has a fixed normalization from } W, \text{ can identify } W
\]

w/ \( m_i \) in elec theoy.

Rescaling \( \bar{\delta} \): also affects \( \bar{\delta} \) in \( K, \lambda \)

changes relations between \( B, \bar{\delta} \leftrightarrow \delta, \bar{\delta} \)

\( \lambda \) changes to preserve (i.e.)

\( \text{SU(0)} \text{ relates anomaly f. } \delta \text{ rescaling w/ SO(F-N)} \)
USE FREEDOM TO RESOLVE $\beta, \varphi$ TO SET $\beta = 1$

**ALTERNATIVELY, RESOLVE $\beta, \varphi$ TO SET $B = \varphi = \varphi^{-1}$**

**BUT:** THEN CANNOT COMPUTE (DIMENSIONAL) $B$.

**WE WILL DO BOTH.**

**CASE:** $m_1 = m_0$

*SK SUPPRESSED BY $\Lambda$, NOT IMPORTANT NEAR $M = 0 = \varphi = 0$*

**EVALUATE** $K(0) = 0$; CORRECTIONS ARE $O(\Lambda^3/\Lambda^3)$ → NEGLIGIBLE

$\Rightarrow K = \frac{\beta}{\Lambda} \text{Tr}(g^2 \mathcal{G} + e^{-2\varphi} g^2) + \frac{\beta}{\Lambda m_0^2} \text{Tr} M M + \ldots$

THEN THIS THEORY MATCHES MACRO MODEL II, USING NOTATION

$\begin{cases} 
\varphi = \omega, \\
\varphi = \varphi, \\
\beta = \frac{m}{\Lambda}, \\
h = \frac{\Lambda}{\Lambda} \\
\Lambda^2 = -m_1, \\
\Lambda m = \Lambda, \\
N = (F-N) 
\end{cases}$

WHERE WE CHOOSE $\beta = 1$, SET $\Lambda$ AS PARAM.

**CASE:** $F = N + 1 \Rightarrow$ MAGNETIC GAUGE GROUP IS TRIVIAL

**SCALE $g, \varphi$ AS IN SECOND CASE ABOVE**

$\beta = \varphi = \varphi^{-1}$

**THEN**

$K = \frac{1}{\Lambda} \text{Tr}(g^2 \mathcal{G} + e^{-2\varphi} g^2) + \ldots \Rightarrow K = \frac{1}{\beta} (\Lambda^{2n-2} (\beta^* B + \beta^* B))$

THE SUPERPOSSENTIAL IS DIFFERENT:

$W = \frac{1}{2} (\Lambda^{2n-1} (B^* M B - \partial \partial M)) + \text{Tr} M M$

(*page 48*)

FOR $N > 2$ THIS IS NEGLIGIBLE NEAR ORIGIN.

$\Rightarrow$ THIS BECOMES SAME AS $N = 1$ THEORY FOR MACRO.

**NOW WE JUST USE RESULTS OF $\beta, \varphi$**

**CONCLUSION:** $N^0 \leq F < \frac{3}{2} N$ WILL SUPPRESS THE MASSES

$\Rightarrow$ SOLO HAS METASTABLE SUSY GROUND STATE NEAR ORIGIN

**IN FACT, COMPACT MODULI SPACE OF METASTABLE VACUUM**

**PARAMETERIZED BY GOLDSTONES**.

**MIRACLE:** WE COULD ESTABLISH EXISTENCE OF METASTABLE STATE EVEN

IN STRONGLY SUSY REGIME; VAC PARAM ON JUST 2

**DIMENSIONAL $\mathbf{B, \beta}$. THIS RESULT EVEN INCLUDES**

NON-SUSY, NON-CENTRAL INPA.
1. Unequal tree-level quark masses, \( m_i \neq m_0 \), \((m_1 < m_N)\)

First consider \( |m_i - m_0| \ll m_0 \ll |m| \) limit.
- Effect of non-degeneracy is small potential on \( m_0 \) state of metastable vac.
- But vac manifold for metastable states is compact so this unequal masses also has metastable vac.

More generally, consider arbitrary \( m_i \ll |m| \).
- Unit \( m_i \) still implies metastable state near origin.
- The macro model I superpotential is modified:
  \[
  W_{\text{vnc}} = h \text{Tr} \phi^0 - h m_i^2 \phi_i^0 \rightarrow W_{\text{vnc}} = h \text{Tr} \phi^0 - h \frac{m_i^2}{m_0^2} h_0^2 \phi_i^0.
  \]

Write \( m_i \) s.t. \( m_1 \geq m_2 \geq \cdots \Rightarrow m_0 \gg 0 \).
- Metastable state \( \phi = 0 \)
- \( \phi^0 = \phi^T = \begin{pmatrix} \phi_0^* \\ \phi_0 \end{pmatrix} \), \( \phi^0 = \text{diag}(\lambda_1, \cdots, \lambda_N) \)
- Nonzero F-terms:
  \[
  F_i; \quad i = (N+1), \cdots, F
  \]
  \[
  V_0 = \sum_{i=(N+1)}^F \lambda_i h_i^2 |1|.
  \]
- Metastable vac \( \Rightarrow \text{casual that } \langle \phi^0 \rangle \) set by \( N \) largest masses.
- Otherwise tree-level spectrum has unstable mode that
  - explodes helplessly to decorrelated vac \( \langle \phi^0 \rangle \) set by \( N \) largest masses.

What about \( m_i \gg |m| \)?
- If all \( m_i \gg |m| \), then no reason to believe metastable state.
- If just one \( m_i \gg |m| \) while other massed small, we can treat as mass perturbation & integrate out.
- Reduce to \( m_i \ll |m| \) less funer (as long as \( F' > N+1 \))
- Our vac eqn analysis still is valid.
- What if we tried to push our luck, \( F = N+1 \rightarrow F' = N \)

2. Changing \( F \) favors \( F \)

\( F = N \) (i.e. \( F = N+1 \rightarrow F' = N \))

If \( m_i \ll m_{i+N} \ll |m| \), we have metastable state.
- \( h_i \neq h_{i+N} \neq 0 \) \( i = 1, \cdots, N \)
- \( h_{i+N} \neq B_0 = 0 \)

Now suppose we can trust this for \( m_{i+N} \gg |m| \).
If we can trust Max II result for $\text{Max} \to [\Lambda]$, then we might understand $F = 1$.

$\textbf{M} = 0 \rightarrow$ gauged NCO constraint: $\text{det} \textbf{M} - \text{BB} = \Lambda^{2n}$

W. smooth $k$ on this scale

Consider tiny around $M = 0$, $B = 0$ = $\Lambda^{N}$

$k$ does on fields together to smooth $c$ at that point:

$k = \frac{1}{\text{Vol} \text{M}} \text{Tr} M^{1/2} + \frac{1}{\text{Vol} \text{M}} \text{Tr} \text{M}^{1/2} + \cdots$

$\lambda^{2N}$ others, two, $R$, mode.

$B = i\Lambda^{n} \lambda^{n}$

$B = i\Lambda^{n} \lambda^{n}$

Turn on $AW = M \text{Tr} \text{M}$ leaves $\sum_{n \geq 0} \lambda^{2n}$ as lead to unified flat dir.

(Reduce $0$ unless $0$ by neglectable higher terms in $k$)

Doubt case W. hope photon 1 and 2 of mass & decay into 1 only (no.)

Such light fields in this case to one reliable call.

Motivated by $\text{Pen}$ from $F = N$ they, we expect these are reasonable.

So far, we've focused on $F = N$ window where $\text{Max} \to 1$, $\text{Max} \leq F$.

Let's think about higher values of $F$.

$F > 3N$:

even this not strongly coupled in $1$, $\text{Max} \to$ dynamical, metastable states not present.

$2N < F < 3N$:

$B \to M$, flow to some unattainable fixed point.

Use again magnetic description but need to modify $k$;

Doubt still valid. Below $\Lambda$, only but non magnetic theory is unreliable. (not does)

For nonzero $M$,

\[ V_{\text{mag}} = (N-2) \left( \frac{\text{det} M}{\Lambda^{3N-2}} \right)^{p - \frac{1}{2}} = (N-2) \left( \frac{\text{det} M}{\Lambda^{3N-2}} \right)^{\frac{p - 1}{2}} \]

Near the origin, scales like $M^{2p} > M^{2}$

\[ \Rightarrow \langle M \rangle = \left( \frac{\text{det} M}{\Lambda^{3N-2}} \right)^{\frac{1}{N-2}} \] (from p 49)

Is too close to the origin for metastable scale

$F = \frac{3}{2} N$:

Suppose 1d phase with $B/C = 2$ vs up B. func.

When scales, use $M^{2}$, again cannot be neglected near origin in this case when under $\Lambda$. $W_{\text{mag}}$ ind of $\Lambda M$.
IF MASSES DEGENERATE \( \Rightarrow U(1) \Leftrightarrow U(1) \times U(1) \) 
GLOBAL SYMMETRY, HUB VACUA BREAK THIS (CONSISTENT IN MASS GAP) 

MEDIABLY VACUUM \( U(1) \Leftrightarrow SU(-N) \times SU(N) \) + ADDITIONAL R 

\( \mathcal{M} = \frac{V(F)}{SU(R-N) \times SU(N)} \) 

THIS HAS A BIGGER UNITARY SPACE THAN THE ZERO SU VAC 

SO COMMONLY YOU FIND MEDIABLY VACUUM

MASS SPECTRUM SUMMARY

- HEMMA HERMATIC STATES \( \text{w} \text{ mass} \sim 1 \) 
- DECAY MAGNETIC STATES
- \( N \) TREE-LEVEL MASSES \( \sim \text{WIG} \sim 1 \) (gauged fields, gauginos) 
- MASSIVE PSEUDOMODULI \( \sim \text{WIG} \) (NON-FAVORABLE MASSIVE 
- MASSLESS SCALARS
- GOSSTONE OF \( \mathcal{M} \) 

MASSLESS FIELDS (NC GOSSTONE)

- \( N \) FERMIONIC PARTIALLY \( \sim \text{PSEUDOMODULI} \) 

CAJOL FEATURE: \( \mathcal{M} \) WANTS NONTRIVIAL TOPOLOGY. 
EXPECT SOLUTIONS \( \mu \) LIFETIME \( \sim \text{MEDIABLY VACUUM} \)

COMMENTS ON LIFETIME OF HS VAC (SEE § 2 FOR MORE DETAILS)

MEDIABLY VACUUM:
\[ \mathcal{O} = 0, \quad \bar{\psi} = \psi = (\begin{pmatrix} 1 \\ 0 \end{pmatrix}) \] 
\[ V_{\psi} = (F-N) \mid N \times \psi \] 

SUSY VACUUM:
\[ \mathcal{O} = \frac{1}{N} \frac{e^{-iF/2} - 1}{e^{-iF/2} + 1} \] 
\[ \psi = \bar{\psi} = 0, \quad V_{\psi} = \mathcal{O} \] 

AS \( \epsilon \rightarrow 0 \), SUSY \( \mu \) N IS PARAMETRICALLY FAR AWAY. 
SEE O'LEARY'S "FACE OF FALSE VAC" FOR CANCELLATION. 

THE POINT IS THAT WE CAN GET \( \tau \sim \text{Age of Universe} \).
1. **Naturality**

\[ G \sim 1/m_{W}, \quad V \sim 1/m^{2}_{W} \quad \Rightarrow \text{NDUEST} \quad (\text{ANSW} \text{ OF } L) \]

\[ \Rightarrow \text{DIFFICES ON FREE PARAMETERS IN} \]

\[ \Rightarrow \text{DOES NOT SATISFY FURST'S} \]

\[ \text{REQUIREMENT THAT ALL LOW SCALES ARE GENERATED DYNAMICALLY} \]

**IDEA:** FIND IDEAS IN SAME IDEAS BUT WERE PLACED ON SOME

MARGINAL OR IRRELEVANT CURVATURES.

\[ \text{EQ. MASS TUNING WJ OR SUPRESSED BY HURGE: } m_{W} \sim \lambda \lambda \lambda \]

\[ \text{OF GEBS DYNAMICAL MODEL, } F_{L} \sim \lambda^{2} \lambda \lambda \lambda \Rightarrow V \sim \frac{\lambda^{2} \lambda^{2} \lambda^{2}}{m_{W}^{2}} \]

2. **Direct Mediation** *(Simpler Model)*

**Such sector has large global sym. \( G \) with \( H \to G \) gauged**

**Identified with (max) of SM gauged group.**

\[ \text{Eg. GROUP } SU(N) \text{ IN NUKA MODE } \]

\[ \text{BELOW A GAUGE GROUP } \xrightarrow{\text{SUBGROUP OF SM}} \]

\[ \text{THEN IDENTIFY } V \text{ AS: } SU(F-N) \times SU(F) \to SU(F-N) \times SU(N) \text{ EXPRESSED DIAGONALLY } \]

\[ \text{INTO } SU(F-N) \times SU(F) \]

\[ \text{BUT: IF WE IDENTIFY } \frac{1}{\sqrt{2}} \text{ SUBGROUPS, WJ H \to G \text{ (MAXIMUM?)} \]

\[ \text{THEN THE GAUGE OF THIS SECTOR } \to \text{ MAXIMUM SU(N) FLAVORS} \]

\[ \text{TOO MANY FLAVORS } \Rightarrow \text{ CAN HAVE DANGEROUS LOW MAJORAS PIONS} \]

3. **E-SUMMATION PROBLEM** *(lots of H or Higgs)*

- **NONABELO CHANCE 6-WIND MASSES \( \Rightarrow \text{E-SYM MUST BE BROKEN} \)**

- **THIS WILL RESTORE SU(6)** *(GENERICALLY)*

- **CAN SOME UN CANCE**

- **OUR THEOREMS (1)** \( \Rightarrow \text{EXACT E-SYM } \Rightarrow \text{HEAVITently} \)

- **ACCIDENTAL E-SYM NEAR ORGAN**

- **SMALL EFFECT OF EXACT E IN MS STATE MAY BE ENOUGH**

- **TO AVOID E-SYM PROBLEM**

- **AS IT STANDS, CAN AVOID HERE WAS DISAPPEAR (200?) E-SYM**

- **WHAT PRODUCES THIS 6-WIND MASS, A \( \text{IF THESE CAN BE EXACTLY BROKEN} \)**

- **IN NUKA ONLY**

**NOTE BOOK**