Realization of spontaneous gauge and supersymmetry breaking vacuum

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based on 1705.00809
collaboration with T. Kobayashi, O. Seto, K. Ueda

Outline

- Introduction
- SUSY breaking associated with gauge symmetry breaking.

  gauge U(1) model

  Pati-Salam
- Summary

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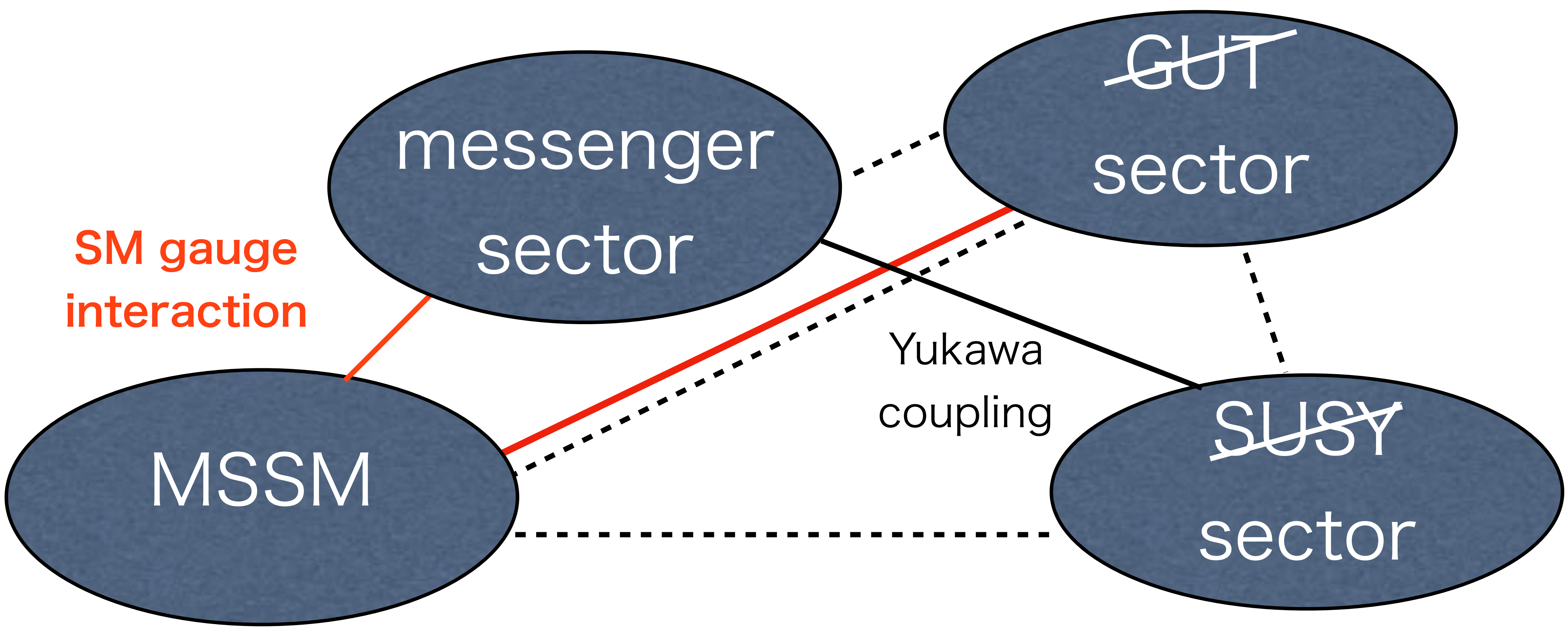

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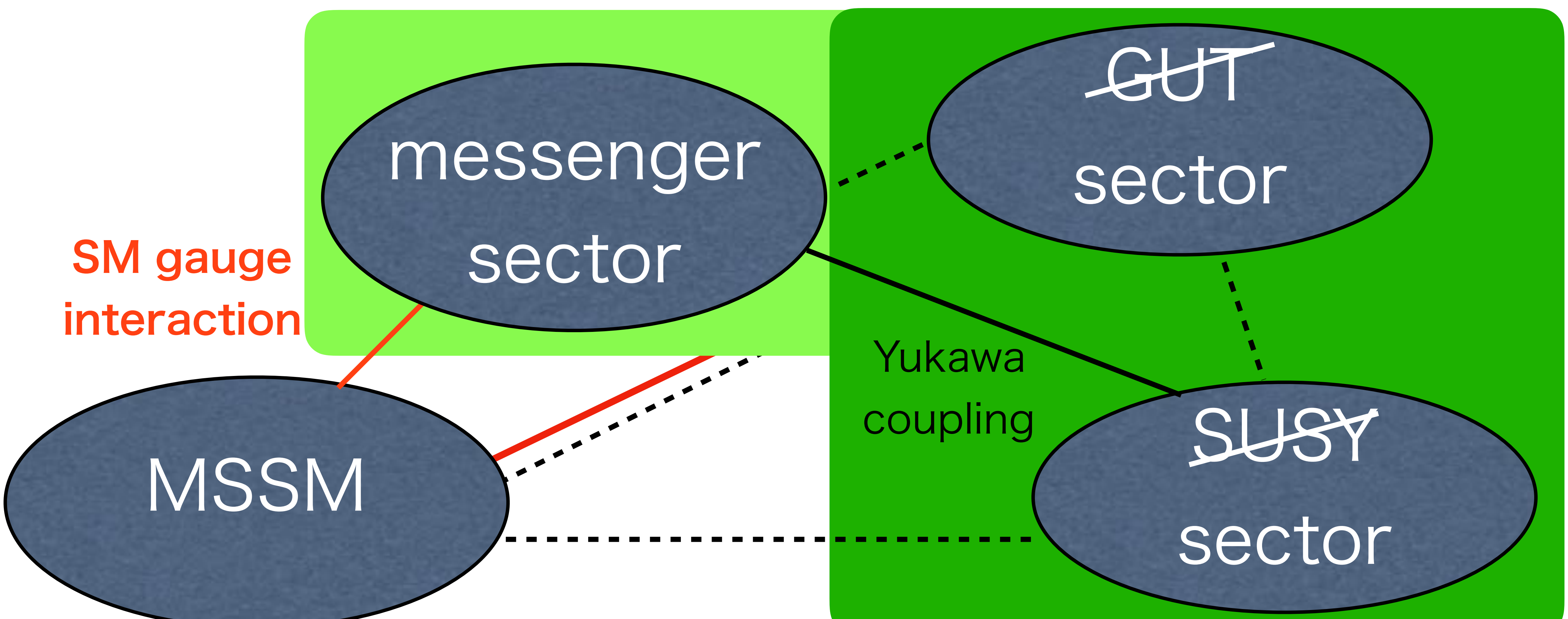

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If SUSY is conserved, $\partial_{\Phi_I} W = 0 \ (V = 0)$

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Phase rotation of X is namely R-symmetry, and it is crucial to SUSY breaking.

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Spontaneous SUSY breaking seems to imply the existence of R-symmetry in the models.

$R_{charge}[W] = 2$

(Nelson,Seiberg,hep-th/9309299)

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Problem 2

The scalar comp. of X may be stabilized by the radiative correction, but not so simple. (Often stabilized at X=0.)

(Shih,hep-th/0703196;Sun,0810.0477)

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**Motivated by those problems, I propose a model where ϕ_+, ϕ_-, X_+, X_- are charged under extra gauge symmetry.
Then, we find a realistic vacuum to cause SUSY breaking in association with gauge symmetry (GUT) breaking.**

SUSY breaking
associated with gauge symmetry breaking

For the demonstration, let me consider the U(1) case:

(Kobayashi, Seto, YO, Ueda, 1705.00809)

Matter contents

Chiral superfield	SM	$U(1)$	$U(1)_R$
$\phi_\pm$	singlet	±1	0
$X_\pm$	singlet	±1	2
X	singlet	0	2

superpotential

$$W = fX + \lambda X\phi_+\phi_- + m_1 X_+\phi_- + m_2 X_-\phi_+$$

U(1) D-term

$$V_D = \frac{g^2}{2}\left(|\phi_+|^2 - |\phi_-|^2 + |X_+|^2 - |X_-|^2\right)^2$$

Important point is that *there is no vacuum where all F-terms are vanishing in this model.*

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$$\partial_X W = f + \lambda \phi_+ \phi_-$$

$$\partial_{X_-} W = m_2 \phi_+$$

$$\partial_{X_+} W = m_1 \phi_-$$

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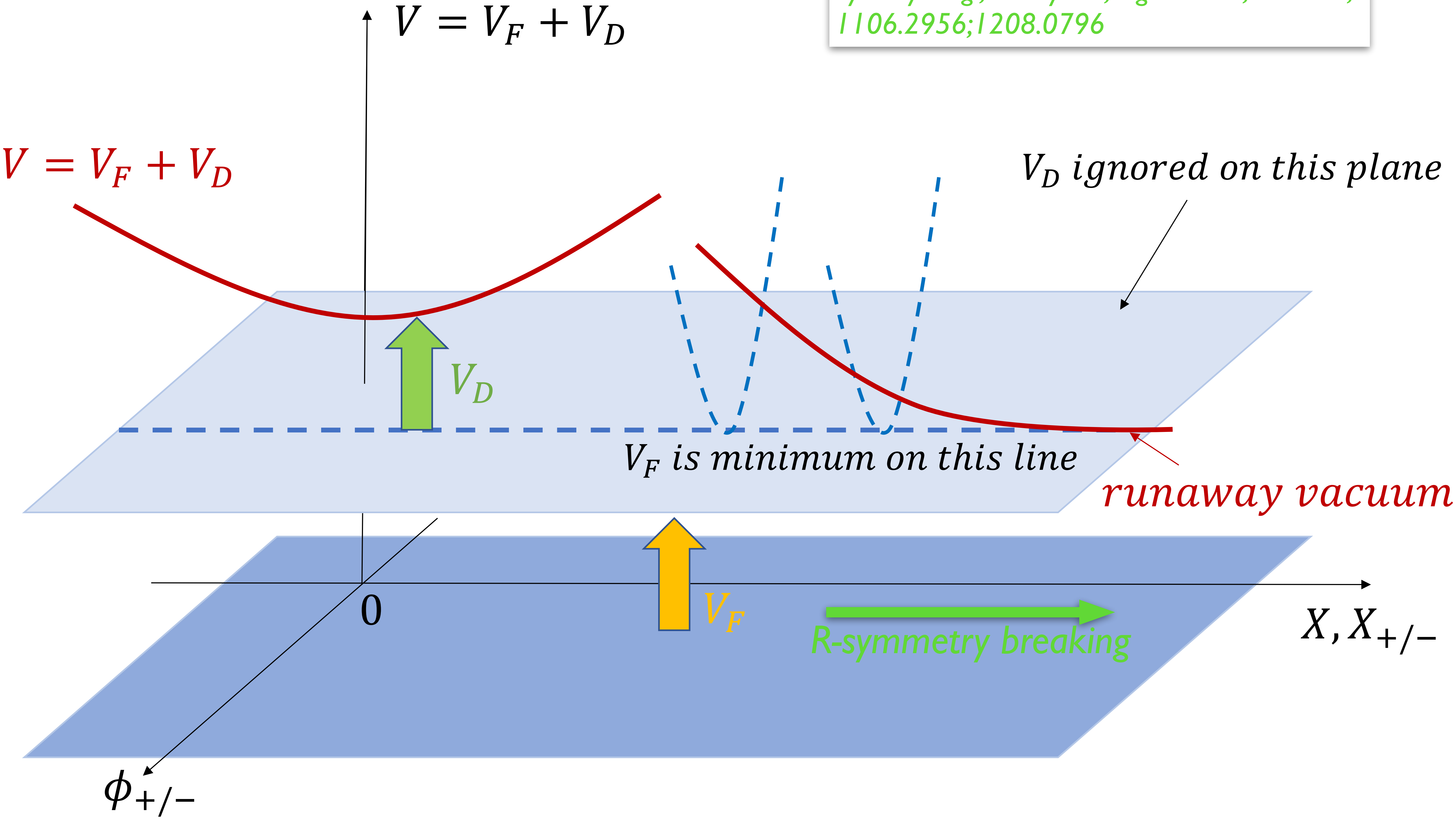
sketch of the scalar potential

Note
This runaway vacuum is proposed by Azeyanagi, Kobayashi, Ogasawara, Yoshioka, 1106.2956;1208.0796



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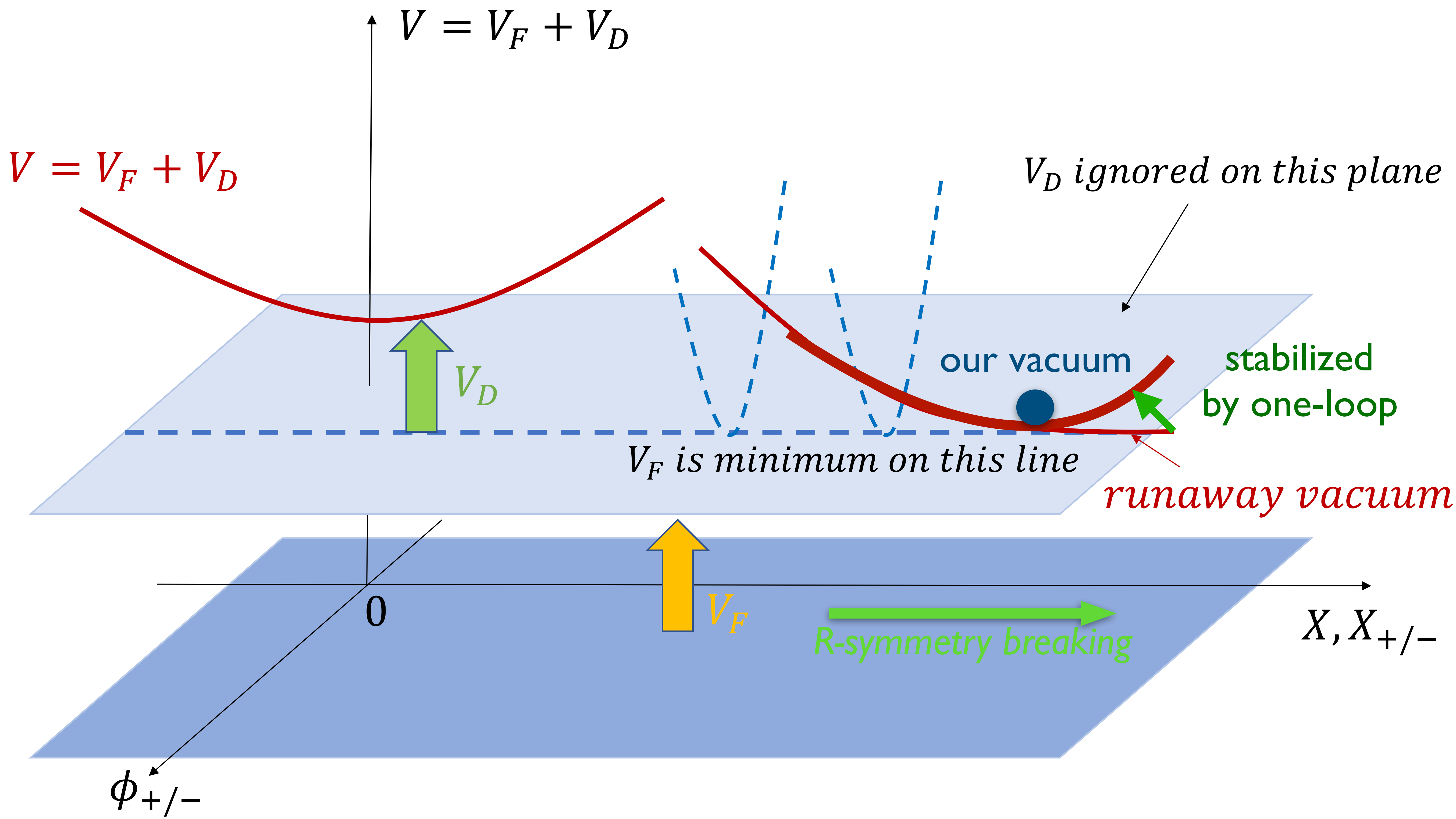

Important points of this vacuum

・There is a runaway direction and stabilized by one-loop correction. Then, ***R-symmetry is also spontaneously broken***.

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・The runaway behavior is one generic feature of this kind of model, where V_F is non-vanishing anywhere.

When $\langle \Phi_I \rangle = v_I$ satisfies $\partial_{\Phi_I} V_F = W_{IJ} \overline{W^J} = 0$

there is flat direction (z) in V_F: $\Phi_I = v_I + \overline{W_I}(v)\, z$

$$V_D = \frac{g_A^2}{2} \left(\Phi_I^\dagger q_{IJ}^A \Phi_L \right)^2 \xrightarrow{\hat{\Phi}_I = v_I + W_I(v) z + \frac{c_I}{z}} V_D|_{W_{IJ}\overline{W_J}=0} = \frac{g_A^2}{2} \left(v_I q_{IJ}^A c_J \frac{1}{z} + c.c. + \mathcal{O}(z^{-2}) \right)$$

because of the gauge symmetry

(Azeyanagi, Kobayashi, Ogasawara, Yoshioka, 1106.2956; 1208.0796)

- We have discussed a simple U(1) model:

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$$U(1) \to \textit{nothing}$$

- We can extend this to GUT symmetry:

If the fields, $\phi_{+/-}$ and X+/-, are charged under GUT symmetry (e.g., Pati-Salam, flipped SU(5) etc.),

$$SU(2)_R \times SU(2)_L \times SU(4) \to SM$$

$$SU(5) \times U(1) \to SM$$

GUT breaking and SUSY breaking are unified.

Let's consider the application to "Pati-Salam" ($SU(4)\times SU(2)_R\times SU(2)_L$).

(Kobayashi, YO, Seto, Ueda, *1705.00809*)

The charge assignment of ϕ+/- and X+/-

$$X_+,\ \phi_+ : (\mathbf{4},\ \mathbf{2},\ \mathbf{1}),\qquad \mathbf{X}_-,\ \phi_- : (\overline{\mathbf{4}},\ \mathbf{2},\ \mathbf{1})$$

Superpotential

$$W = fX + \lambda X Tr(\phi_+\phi_-) + m_1 Tr(X_+\phi_-) + m_2 Tr(X_-\phi_+)$$

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We can find the runaway direction that breaks R-symmetry, and we obtain the SUSY breaking vacuum at the one-loop.

$$\langle\phi_\pm\rangle = \begin{pmatrix} \mp\frac{F}{m_{1,2}} & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \qquad \langle X_\pm\rangle = \begin{pmatrix} \pm z_0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \qquad \langle F_{X_\pm}\rangle = \begin{pmatrix} \pm F & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$$

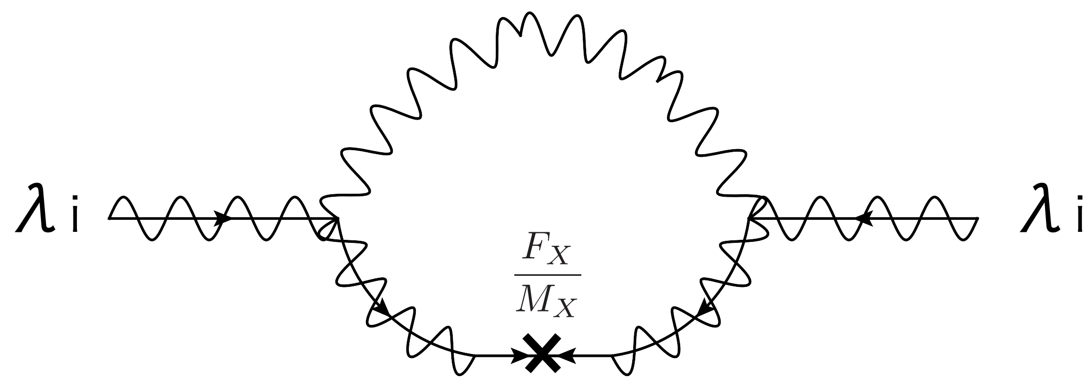
$SU(2)_R \times SU(4) \rightarrow SU(3)\times U(1)_Y$

- Another interesting point of this setup is

gaugino mass is generated by the gauge messenger contributions.

Massive gauge bosons

from SU(2)R×SU(4) breaking



The fermionic partners

gauge messenger contribution

$$M_a = \frac{\alpha_a}{4\pi} \Delta b_a \frac{F}{z_0}$$

where $(\Delta b_Y\ \Delta b_2,\ \Delta b_3) = (-10/3,\ 0,\ -1)$

Summary

・How to break SUSY spontaneously is one of the crucial issues.

・SUSY breaking model generally has R-symmetry.

→ *Both R-symmetry and SUSY should break down at our vacuum.*

・I introduce one type of SUSY breaking models:

Gauge symmetry causes a runaway direction to break R-symmetry. Our vacuum is induced by stabilizing the runaway according to the one-loop correction.

・I gave some comments on the applications to GUT models in our paper. The detail will be shown near future.

END

Backup

Comments (Kobayashi, YO, Seto, Ueda, 1705.00809)

- *Wino mass is vanishing at LO in the Pati-Salam. Other contributions like gravity mediation may be required.*

- *This mechanism can be applied to other GUTs, e.g., flipped SU(5).*

- *One issue of this mechanism is about tachyonic masses of sfermions.*

  one-loop contribution: almost vanishing at our vacuum.

  two-loop contribution: we need more careful study.

- *Spontaneous R-symmetry breaking leads massless R-axion.*

  Gauged $U(1)_A$ instead of R-symmetry does work well.

N. Maekawa, Y. Shigekami, M. Yoshida, 1712.05107

Gauged U(1)A Model

(Maekawa, YO, Shigekami, Yoshida, 1712.05107)

Matter contents

Chiral superfield	SM	$U(1)_A$
S	singlet	$s \gg 1$
Θ	singlet	-1

Superpotential

$$W = a_0 + a_1 S \left(\frac{\Theta}{\Lambda}\right)^s + \frac{a_2}{2}\left(S\left(\frac{\Theta}{\Lambda}\right)^s\right)^2 + \frac{a_3}{6}\left(S\left(\frac{\Theta}{\Lambda}\right)^s\right)^3 + \dots$$

$W_{eff} \approx a_0 + (a_1 \lambda^s) S$ *is obtained when* $\lambda \ll 1$. $\left(\lambda \equiv \left\langle \frac{\Theta}{\Lambda} \right\rangle\right)$

U(1)A D-term potential

$$V_D = \frac{g^2}{2}\left(\xi^2 - |\Theta|^2 + s|S|^2\right)^2$$

Effective Potential for S in SUGRA

$$V_{eff} = f^2 + |W_{\Theta S}||S|^2 + g^2 s D_0 |S|^2 + \frac{1}{2} g^2 s^2 |S|^4$$

$$-3\frac{a_0^2}{M_p^2} + (S + S^\dagger)\frac{a_0 f}{M_p^2} + \frac{a_0^2}{M_p^2}|S|^2 + \ldots$$

(originated from constant term, a_0, in W)