Phase Transition of NLSUSY Space-time
and
Unity of Nature

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OUTLINE

1. Motivation

SUSY and its spontaneous breakdown are profound notions related to the space-time symmetry, therefore, to be studied not only in the low energy particle physics but also in the cosmology, i.e. in the framework necessarily accomodating graviton as well.

We have found group theoretically that

@The SM with just three generations of quarks and leptons emerges from a single irreducible representation of SO(10) superPoincaré(sP),

@SO(10) sP with $\underline{\mathbf{10}} = \underline{\mathbf{5}} + \underline{\mathbf{5}}^*, 5_{SU(5)GUT}$ for $SO(10) \supset SU(5)$ is minimal and unique among SO(N) sP.

SO(N>8) Linear(L) SUSY $\Longrightarrow$ no-go theorem in S-matrix !

How to find a field theoretical breakthrough:

We show in this talk that

- the nonlinear(NL) SUSY invariant coupling of spin $\frac{1}{2}$ fermion with spin 2 graviton is crucial to circumvent the no-go theorem of S-matrix arguments for SO(N$>$8) Linear SUSY.

- This is attributed to the geometrical structure of particular empty space-time unifying two notions:

the object(spin $\frac{1}{2}$ NLSUSY) and the background space-time manifold(general relativity).

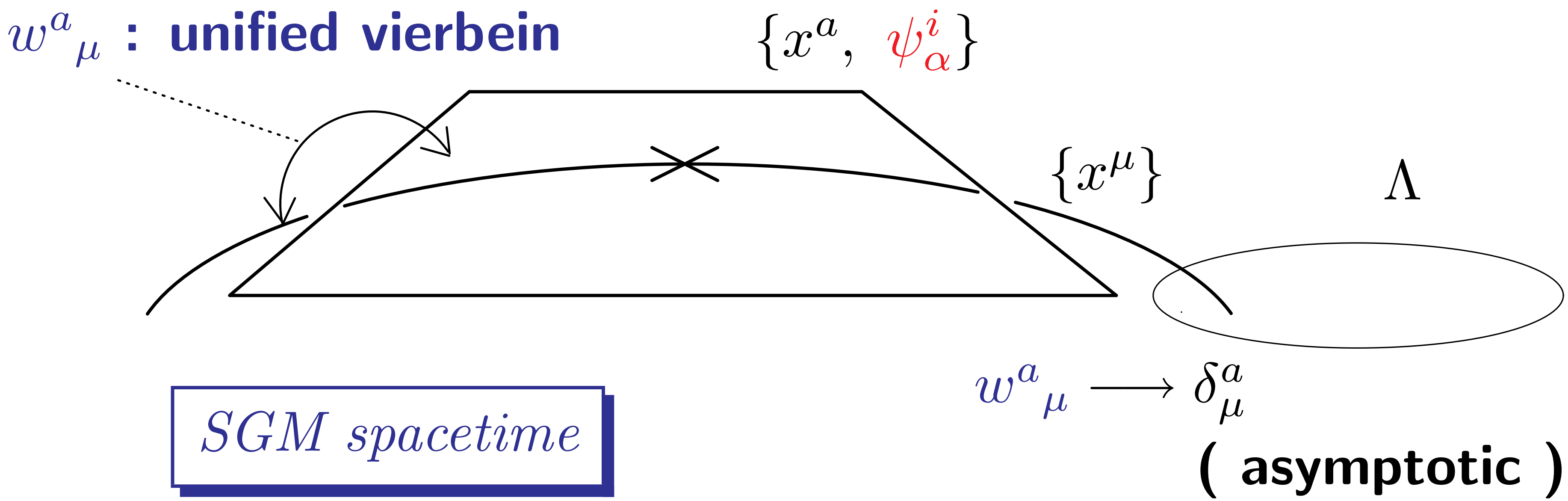
- We are tempted to speculate that there may be a certain composite structure for particles and a particular superfluidity of space-time and matter far beyond the SM.

2.Nonlinear Supersymmetric General Relativity (NLSUSY GR)

We extend the geometrical arguments of Einstein general relativity(EGR) on Riemann space-time to new space-time inspired by nonlinear(NL) SUSY :

The tangent space-time of new space-time is specified by the SL(2,C) Grassman coordinates ψ_α of NLSUSY besides the ordinary SO(1,3) Minkowski coordinate x^a,

i.e. the local NLSUSY degrees of freedom(d.o.f)ψ_α turning subsequently to the NG fermion d.o.f. (called $superon$ hereafter) of the coset space $\frac{superGL(4,R)}{GL(4,R)}$ and x^a are attached at every curved space-time point.



(Note that locally homomorphic SO(1,3) and SL(2,C) are non-compact groups for space-time d.o.f. which are analogous to SO(3) and SU(2) compact groups for gauge d.o.f. of 't Hooft-Polyakov monopole.)

We have found that parallel arguments to the Einstein genaral relativity(EG) theory on Riemann space-time is possible on new (SGM) space-time as well.

We have obtained the following N-extended NLSUSY GR action of the vacuum EH-type in new empty space-time.

For selfcontained argumants a quik review of NLSUSY is given.

A brief review of NLSUSY:

- **Take flat space-time specified by x^a and ψ_α.**
- **Consider one form $\omega_a = dx_a - \frac{\kappa^2}{2i}(\bar{\psi}\gamma^a d\psi - d\bar{\psi}\gamma^a\psi)$,**
- **$\delta\omega_a = 0$ under $\delta x_a = \frac{i\kappa^2}{2}(\bar{\zeta}\gamma^a\psi - \bar{\psi}\gamma^a\zeta)$ and $\delta\psi = \zeta$ with a global spinor parameter ζ and κ is a dimensionfull(l^4) arbitrary constant.**
- **An invariant acction($\sim$ invariant volume) is obtained:**

$$S = -\frac{1}{2\kappa^2}\int \omega_0 \wedge \omega_1 \wedge \omega_2 \wedge \omega_3 = \int d^4x L_{VA}$$

- **N=1 Volkov-Akulov model of NLSUSY is given by**

$$L_{\rm VA} = -\frac{1}{2\kappa^2}|w| = -\frac{1}{2\kappa^2}\left[1 + t^a{}_a + \frac{1}{2}(t^a{}_a t^b{}_b - t^a{}_b t^b{}_a) + \cdots\right],$$

$$|w| = \det w^a{}_b = \det(\delta^a_b + t^a{}_b),$$

$$t^a{}_b = -i\kappa^2(\bar{\psi}\gamma^a\partial_b\psi - \bar{\psi}\gamma^a\partial_b\psi),$$

which is invariant under N=1 NLSUSY transformation,

$$\delta_\zeta\psi = \frac{1}{\kappa}\zeta - i\kappa(\bar{\zeta}\gamma^a\psi - \bar{\zeta}\gamma^a\psi)\partial_a\psi. \longleftrightarrow$$ **NG fermioon for SB SUSY**

- **ψ is NG fermion (the coset space coordinate) of $\frac{Super-Poincare}{Poincare}$.**

N-extended NLSUSY GR action:

$$L_{NLSUSYGR}(w) = \frac{c^4}{16\pi G}|w|(\Omega(w) - \Lambda), \tag{1}$$

$$|w| = \det w^a{}_\mu = \det(e^a{}_\mu + t^a{}_\mu(\psi)), \tag{2}$$

$$t^a{}_\mu(\psi) = \frac{\kappa^2}{2i}(\bar{\psi}^I \gamma^a \partial_\mu \psi^I - \partial_\mu \bar{\psi}^I \gamma^a \psi^I), (I = 1, 2, .., N) \tag{3}$$

- $w^a{}_\mu(x)(= e^a{}_\mu + t^a{}_\mu(\psi))$: **the unified vierbein of new space-time,**
- $\Omega(w)$: **the unified scalar curvature of new space-time,**
- $e^a{}_\mu$: **the ordinary vierbein for the local SO(1,3) of EGR,**
- $t^a{}_\mu(\psi)$: **the mimic vierbein for the local SL(2,C) composed of the stress-energy-momentum of NG fermion $\psi(x)^I$(called superons),**
- $s_{\mu\nu} \equiv w^a{}_\mu \eta_{ab} w^b{}_\nu$ **and** $s^{\mu\nu}(x) \equiv w^\mu{}_a(x) w^{\nu a}(x)$ **are unified metric tensors of new space-time.**
- G : **(Newton) gravitational constant.**
- Λ : **(*small*) cosmological constant indicating the NLSUSY structure of new space-time.**

- **No-go theorem has been circumvented in a sense that**

SO(N>8) SUSY with the non-trivial gravitational interaction and with $\Delta J = \frac{3}{2}$ has been constructed by using NLSUSY, i.e. the vacuum degeneracy.

• **Remarkably the constatnt κ^2 with the dimension $(length)^4$, which is arbitrary in NLSUSY model so far, is now fixed to**

$$\kappa^2 = (\frac{c^4\Lambda}{8\pi G})^{-1}$$

by NLSUSY GR scenario.

• **Also the signature of the cosmological term is now fixed uniuely to give the correct signature to the kinetic term of $\psi(x)$,**

which allows the dark energy density interpretation of Λ
for the present universe acceleration.

Symmetries of NLSUSY GR(N-extended SGM action)

NLSUSY GR action is invariant at least under the following space-time symmetries which is isomorophic to super-Poincaré(SP):

$$[\mathrm{NLSUSY}] \otimes [\mathrm{local\ GL(4,R)}] \otimes [\mathrm{local\ Lorentz}] \otimes [\mathrm{local\ spinor\ translation}] \tag{4}$$

and the following internal symmetries for N-extended NLSUSY GR (with N-superons ψ^I $(I = 1, 2, ..N)$) :

$$[\mathrm{global\ SO(N)}] \otimes [\mathrm{local\ U(1)^N}] \otimes [\mathrm{chiral}]. \tag{5}$$

- **NLSUSY GR (1) is invariant under the new NLSUSY transformation;**

$$\delta_{\zeta^I}\psi = \frac{1}{\kappa}\zeta^I - i\kappa\bar{\zeta}^J\gamma^\rho\psi^J\partial_\rho\psi^I, \quad \delta_\zeta e^a{}_\mu = i\kappa\bar{\zeta}^J\gamma^\rho\psi^J\partial_{[\mu}e^a{}_{\rho]}, \tag{6}$$

which induce GL(4,R) transformations on $w^a{}_\mu$ and the unified metric $s_{\mu\nu}$

$$\delta_\zeta w^a{}_\mu = \xi^\nu\partial_\nu w^a{}_\mu + \partial_\mu\xi^\nu w^a{}_\nu, \quad \delta_\zeta s_{\mu\nu} = \xi^\kappa\partial_\kappa s_{\mu\nu} + \partial_\mu\xi^\kappa s_{\kappa\nu} + \partial_\nu\xi^\kappa s_{\mu\kappa}, \tag{7}$$

for a constant spinor parameter ζ , $\partial_{[\rho}e^a{}_{\mu]} = \partial_\rho e^a{}_\mu - \partial_\mu e^a{}_\rho$, $\xi^\rho = -i\kappa\bar{\zeta}^I\gamma^\rho\psi^I$).
The commutators of two new NLSUSY transformations (6) on ψ^I and $e^a{}_\mu$ are GL(4,R),

$$[\delta_{\zeta_1}, \delta_{\zeta_2}]\psi^I = \Xi^\mu\partial_\mu\psi^I, \quad [\delta_{\zeta_1}, \delta_{\zeta_2}]e^a{}_\mu = \Xi^\rho\partial_\rho e^a{}_\mu + e^a{}_\rho\partial_\mu\Xi^\rho, \tag{8}$$

where $\Xi^\mu = 2i\bar{\zeta}^I{}_1\gamma^\mu\zeta^I{}_2 - \xi_1^\rho\xi_2^\sigma e_a{}^\mu\partial_{[\rho}e^a{}_{\sigma]}$.

i.e. new NLSUSY (6) is the square-root of GL(4,R);

$$[\delta_1, \delta_2] = \delta_{GL(4R)}, \quad \text{i.e.} \quad \delta_1 \sim \sqrt{\delta_{GL(4R)}}.$$

c.f. SUGRA: $[\delta_1, \delta_2] = \delta_P \underline{+\delta_L + \delta_g}$

- **The ordinary GL(4R) invariance of $L(w)$ is manifest by the construction.**

c.f. SUGRA

$$[\delta_1, \delta_2] = \delta_P \underline{+\delta_L + \delta_g}$$

- **NLSUSY GR (1) is invariant under the local Lorentz transformation;**

$$\delta_L w^a{}_\mu = \epsilon^a{}_b w^b{}_\mu \tag{9}$$

with the local parameter $\epsilon_{ab} = (1/2)\epsilon_{[ab]}(x)$

or equivalently on ψ^i **and** $e^a{}_\mu$

$$\delta_L \psi^I = -\frac{i}{2}\epsilon_{ab}\sigma^{ab}\psi^I, \quad \delta_L e^a{}_\mu = \epsilon^a{}_b e^b{}_\mu + \frac{\kappa^4}{4}\varepsilon^{abcd}\bar{\psi}^I)\gamma_5\gamma_d\psi^I(\partial_\mu \epsilon_{bc}). \tag{10}$$

The local Lorentz transformation forms a closed algebra, for example, on $e^a{}_\mu(x)$

$$[\delta_{L_1}, \delta_{L_2}]e^a{}_\mu = \beta^a{}_b e^b{}_\mu + \frac{\kappa^4}{4}\varepsilon^{abcd}\bar{\psi}^j\gamma_5\gamma_d\psi^j(\partial_\mu \beta_{bc}), \tag{11}$$

where $\beta_{ab} = -\beta_{ba}$ **is defined by** $\beta_{ab} = \epsilon_{2ac}\epsilon_1{}^c{}_b - \epsilon_{2bc}\epsilon_1{}^c{}_a$**.**

Note that the NG fermion d.o.f. ψ can be transformed away neither by the local spinor translation(LST) nor by the local GL(4R).

• For LST with the local spinor paremeter $\theta(x)$;
$\delta\psi = \theta$, $\delta e^a{}_\mu = -i\kappa^2\bar{\theta}\gamma^a\partial_\mu\psi + \bar{\psi}\gamma^a\partial_\mu\theta)$, $[\delta_1, \delta_2] = 0$
$w(e + \delta e, t(\psi + \delta\psi)) = w(e + t(\psi), 0) = w(e, t(\psi))$ under $\theta(x) = -\psi(x)$ as indicated $\delta w^a{}_\mu(x) = 0$,

• for GL(4R), once GL(4R) is performed for $L(w) \to L(e)$, then the subsequent ordinary GL(4R) on the consequent EH action $L(e)$ would bocome pathological(restricted) and the graviton as well.

No-go theorem in the S-matrix arguments has been circumvented in a sense that $N > 8$-extended SUSY invariant theory with graviton is constructed by using NLSUSY, i.e. the vacuum degeneracy.

Big Decay of new space-time (to the true vacuum):

New space-time described by NLSUSY GR action (1) is unstable due to the global NLSUSY structure of tangent space-time and breakes down spontaneously to ordinary Riemann space-time(EH action) with superons(NG fermion) as follows (called SGM action) :

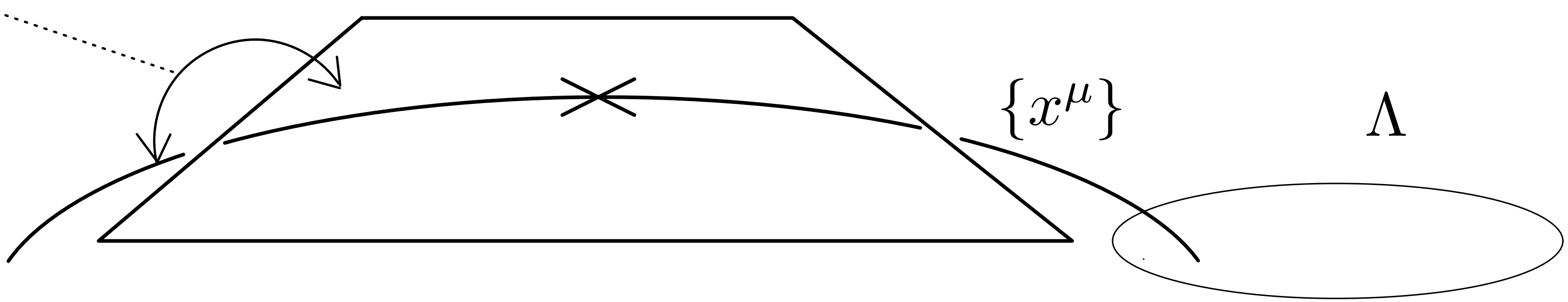
$$L_{NLSUSYGR}(w) = L_{SGM}(e,\psi) = \frac{c^4}{16\pi G}|e|\{R(e) - \Lambda + \tilde{T}(e,\psi)\}. \qquad (12)$$

- $R(e)$: the scalar curvature of EH action
- Λ : the cosmological term
- $\tilde{T}(e,\psi)$: the kinetic term and the gravitational interaction of superon.
- $L_{SGM}(e,\psi)$ reduces to N-extended NLSUSY action

with $\kappa^2 = (\frac{c^4\Lambda}{8\pi G})^{-1}$ in asymptotic Riemann-flat($e^a{}_\mu(x) \to \delta^a{}_\mu$) space-time.

$w^a{}_\mu$: unified vierbein

$\{x^a,\ \psi^i_\alpha\}$



$w^a{}_\mu \longrightarrow \delta^a_\mu$

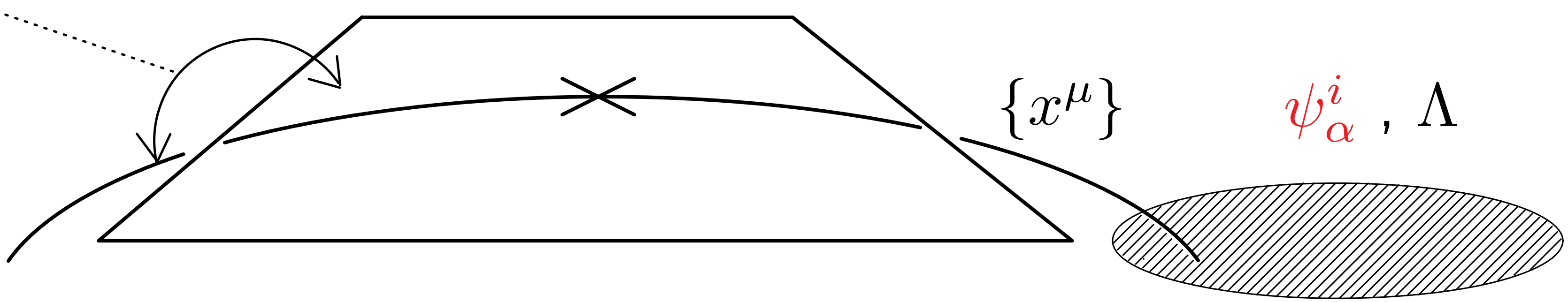
(asymptotic)

SGM spacetime

$\Downarrow$(Big Decay)

$e^a{}_\mu$: ordinary vierbein

$\{x^a\}$



$e^a{}_\mu \longrightarrow \delta^a_\mu$

(asymptotic)

Riemann spacetime $\oplus$ matter

3. NL/L SUSY Relation and Linearization of NLSUSY

$L_{SGM}(e, \psi)$ **is highly nonlinear theory, therefore it is not easy to see the low energy behaviours!**

- **However, N-LSUSY theory related(equivalent) to N-NLSUSY theory can be constructed by the SUSY algebra (symmetry).**

$$\Longleftrightarrow \text{ NL/L SUSY relations}$$

- **The systematics of the linearization for establishing NL/L SUSY relation are well understood for N=1 SUSY in flat space-time.**

NL/L SUSY relation describes the vacuum structure of SGM action.

Extracting low energy particle physics of SGM action :

- we consider

N=2 SGM in asymptotic Riemann-flat ($e^a{}_\mu(x) \to \delta^a{}_\mu$) space-time,
where

$$L_{\mathrm{N=2SGM}}(e,\psi) \to L_{\mathrm{N=2NLSUSY}}(\psi) \ .$$

- **Note that N=2 SUSY gives the minimal and physical (realistic) SUSY model in SGM scenario.**

Because $J^P = 1^-$ U(1) geuge field does not appear in $N=1$ SUSY.

$\Longrightarrow$

N=2 MSSM is the minimal realistic model in SGM scenario.

The arguments are in two dimensional space-time for simplicity .

([N=1, d=4 NLSUSY] $\neq$ [N=2, d=2 NLSUSY])

- **N=2, d=2 NLSUSY model is given by**

$$L_{\rm VA} = -\frac{1}{2\kappa^2}|w| = -\frac{1}{2\kappa^2}\left[1 + t^a{}_a + \frac{1}{2}(t^a{}_a t^b{}_b - t^a{}_b t^b{}_a) + \cdots\right], \qquad (13)$$

where,

$|w| = \det w^a{}_b = \det(\delta^a_b + t^a{}_b)$,
$t^a{}_b = -i\kappa^2(\bar{\psi}_j \gamma^a \partial_b \psi^j - \bar{\psi}_j \gamma^a \partial_b \psi^j)$, $(j = 1, 2)$,

which is invariant under N=2 NLSUSY transformation,

$\delta_\zeta \psi^j = \frac{1}{\kappa}\zeta^j - i\kappa(\bar{\zeta}_k \gamma^a \psi^k - \bar{\zeta}_k \gamma^a \psi^k)\partial_a \psi^j, (j = 1, 2)$.

N=2 LSUSY Theory:

- **Helicity states of N=2 vector supermultiplet:**

$$\begin{pmatrix} +1 \\ +\frac{1}{2}, \ +\frac{1}{2} \\ 0 \end{pmatrix} + [\mathrm{CPTconjugate}]$$

correspond to WZ N=2 LSUSY off-shell vector supermultiplet: $(v^a, \lambda^i, A, \phi, D;$**i=1,2**$)$**.**

- **Helicity states of N=2 scalar supermultiplet:**

$$\begin{pmatrix} +\frac{1}{2} \\ 0, \ 0 \\ -\frac{1}{2} \end{pmatrix} + [\mathrm{CPTconjugate}]$$

correspond to N=2 LSUSY two scalar supermultiplets: **(**χ**,** B^i**,** ν**,** F^i**;** $i = 1, 2$**).**

- **The most genaral $N=2$ LSUSYQED action :**

$$L_{\mathrm{N=2LSUSYQED}} = L_{V0} + L'_{\Phi 0} + L_e + L_{Vf} + L_{Vm}, \tag{14}$$

$$\begin{aligned}
L_{V0} &= -\frac{1}{4}(F_{ab})^2 + \frac{i}{2}\bar{\lambda}^i \partial\!\!\!/ \lambda^i + \frac{1}{2}(\partial_a A)^2 + \frac{1}{2}(\partial_a \phi)^2 + \frac{1}{2}D^2 - \frac{\xi}{\kappa}D, \\
L'_{\Phi 0} &= \frac{i}{2}\bar{\chi}\partial\!\!\!/ \chi + \frac{1}{2}(\partial_a B^i)^2 + \frac{i}{2}\bar{\nu}\partial\!\!\!/ \nu + \frac{1}{2}(F^i)^2, \\
L_e &= e\left\{ i v_a \bar{\chi}\gamma^a \nu - \epsilon^{ij} v^a B^i \partial_a B^j + \frac{1}{2}A(\bar{\chi}\chi + \bar{\nu}\nu) - \phi\bar{\chi}\gamma_5 \nu \right. \\
&\quad \left. + B^i(\bar{\lambda}^i \chi - \epsilon^{ij}\bar{\lambda}^j \nu) - \frac{1}{2}(B^i)^2 D \right\} + \frac{1}{2}e^2({v_a}^2 - A^2 - \phi^2)(B^i)^2, \\
L_{Vf} &= f\{A\bar{\lambda}^i\lambda^i + \epsilon^{ij}\phi\bar{\lambda}^i\gamma_5\lambda^j + (A^2 - \phi^2)D - \epsilon^{ab}A\phi F_{ab}\}, \\
L_{Vm} &= -\frac{1}{2}m\ (\bar{\lambda}^i\lambda^i - 2AD + \epsilon^{ab}\phi F_{ab}).
\end{aligned} \tag{15}$$

To see explicitly the local gauge invariance of the action, we define a complex (Dirac) spinor field χ_D and complex scalar fields (B^i, F^i) by

$$\chi_D = \frac{1}{\sqrt{2}}(\chi + i\nu), \quad B = \frac{1}{\sqrt{2}}(B^1 + iB^2), \quad F = \frac{1}{\sqrt{2}}(F^1 - iF^2), \tag{16}$$

and substitute them into $S'_{\Phi 0} + S_e$ in the action we obtain

$$\begin{aligned} S'_{\Phi 0} + S_e = & \int d^2x \{ i\bar{\chi}_D \not{\mathcal{D}} \chi_D + |\mathcal{D}_a B|^2 + |F|^2 \\ & + e(\bar{\chi}_D \lambda B + \bar{\lambda}\chi_D B^* - D|B|^2 + \bar{\chi}_D \chi_D A + i\bar{\chi}_D \gamma_5 \chi_D \phi) \\ & - e^2(A^2 + \phi^2)|B|^2 \} + [\text{ surface term }], \end{aligned} \tag{17}$$

with the covariant derivative $\mathcal{D}_a = \partial_a - iev_a$ and $\lambda = \frac{1}{\sqrt{2}}(\lambda^1 - i\lambda^2)$.

We can see the action is invariant under the ordinary local $U(1)$ gauge transformations,

$$
\begin{aligned}
(\chi_D, B, F) &\quad\rightarrow\quad (\chi'_D, B', F')(x) = e^{i\theta(x)}(\chi_D, B, F)(x), \\
v_a &\quad\rightarrow\quad v'_a(x) = v_a(x) + \frac{1}{e}\partial_a \theta(x).
\end{aligned}
\tag{18}
$$

The commutor algebra for the fields (16) is also computed as

$$
[\delta_{Q1}, \delta_{Q2}] = \delta_g(\mathcal{D}), \tag{19}
$$

where $\delta_g(\mathcal{D})$ means a gauge covariant transformation according to $\mathcal{D} = \Xi^a \partial_a + ie\theta$.

$L_{\mathrm{N=2LSUSYQED}}$ **is invariant under** $N=2$ **LSUSY parametrized by** ζ^i**.**

- **For the vector off-shell supermultiplet:**

$$
\begin{aligned}
&\delta_\zeta v^a = -i\epsilon^{ij}\bar{\zeta}^i\gamma^a\lambda^j, \\
&\delta_\zeta \lambda^i = (D - i\partial\!\!\!/ A)\zeta^i + \frac{1}{2}\epsilon^{ab}\epsilon^{ij}F_{ab}\gamma_5\zeta^j - i\epsilon^{ij}\gamma_5\partial\!\!\!/\phi\zeta^j, \\
&\delta_\zeta A = \bar{\zeta}^i\lambda^i, \\
&\delta_\zeta \phi = -\epsilon^{ij}\bar{\zeta}^i\gamma_5\lambda^j, \\
&\delta_\zeta D = -i\bar{\zeta}^i\partial\!\!\!/\lambda^i.
\end{aligned}
\tag{20}
$$

$$
[\delta_{Q1}, \delta_{Q2}] = \delta_P(\Xi^a) + \delta_g(\theta),
\tag{21}
$$

where $\Xi^a = 2i\bar{\zeta}_1^i\gamma^a\zeta_2^i$ **and** $\delta_g(\theta)$ **is the** $U(1)$ **gauge transformation only for** v^a **with** $\theta = -2(i\bar{\zeta}_1^i\gamma^a\zeta_2^i\ v_a - \epsilon^{ij}\bar{\zeta}_1^i\zeta_2^j A - \bar{\zeta}_1^i\gamma_5\zeta_2^i\phi)$**.**

- **For the two scalar off-shell supermultiplets:**

$$
\begin{aligned}
\delta_\zeta \chi &= (F^i - i\partial\!\!\!/ B^i)\zeta^i - e\epsilon^{ij} V^i B^j, \\
\delta_\zeta B^i &= \bar{\zeta}^i \chi - \epsilon^{ij} \bar{\zeta}^j \nu, \\
\delta_\zeta \nu &= \epsilon^{ij}(F^i + i\partial\!\!\!/ B^i)\zeta^j + eV^i B^i, \\
\delta_\zeta F^i &= -i\bar{\zeta}^i \partial\!\!\!/ \chi - i\epsilon^{ij}\bar{\zeta}^j \partial\!\!\!/ \nu \\
&\quad -e\{\epsilon^{ij}\bar{V}^j \chi - \bar{V}^i \nu + (\bar{\zeta}^i \lambda^j + \bar{\zeta}^j \lambda^i) B^j - \bar{\zeta}^j \lambda^j B^i\}, \\
&\quad [\delta_{\zeta_1}, \delta_{\zeta_2}]\chi = \Xi^a \partial_a \chi - e\theta\nu, \\
&\quad [\delta_{\zeta_1}, \delta_{\zeta_2}]B^i = \Xi^a \partial_a B^i - e\epsilon^{ij}\theta B^j, \\
&\quad [\delta_{\zeta_1}, \delta_{\zeta_2}]\nu = \Xi^a \partial_a \nu + e\theta\chi, \\
&\quad [\delta_{\zeta_1}, \delta_{\zeta_2}]F^i = \Xi^a \partial_a F^i + e\epsilon^{ij}\theta F^j, \qquad (22)
\end{aligned}
$$

with $V^i = iv_a\gamma^a\zeta^i - \epsilon^{ij}A\zeta^j - \phi\gamma_5\zeta^i$ **and the U(1) gauge parameter** θ**.**

The NL/L SUSY relation:

$$L_{\mathrm{N=2LSUSYQED}}(v_a, \lambda, \phi, ..) \; = L_{\mathrm{N=2NLSUSY}}(\psi) + [\text{surface terms}(\psi)], \tag{23}$$

is established by SUSY invariant relations:

• **SUSY invariant relations express uniquely all component fields of LSUSY supermultiplet as the composites of superons ψ_j of NLSUSY:**

$$\sim \kappa^{n-1}(\psi^i)^n|w| + \cdots. \tag{24}$$

• **SUSY invariant relations reproduce the familiar LSUSY transformations of the component fields of the supermultiplet by taking the NLSUSY transformations of the constituent superons ψ^j.**

- **SUSY invariant relationsns for $N = 2$ minimal off-shell vector supermultiplet:**

$$
\begin{aligned}
v^a &= -\frac{i}{2}\xi\kappa\epsilon^{ij}\bar{\psi}^i\gamma^a\psi^j|w|, \\
\lambda^i &= \xi\psi^i|w|, \\
A &= \frac{1}{2}\xi\kappa\bar{\psi}^i\psi^i|w|, \\
\phi &= -\frac{1}{2}\xi\kappa\epsilon^{ij}\bar{\psi}^i\gamma_5\psi^j|w|, \\
D &= \frac{\xi}{\kappa}|w|.
\end{aligned}
\tag{25}
$$

- **Note that the global SU(2) emerges for N=2 SGM.**

$\longrightarrow d = 4$ **as well.**

- **SUSY invariant relations for $N = 2$ minimal off-shell scalar supermultiplet:**

$$
\begin{aligned}
\chi &= \xi^i \left[\psi^i |w| + \frac{i}{2}\kappa^2 \partial_a \{ \gamma^a \psi^i \bar{\psi}^j \psi^j |w| \} \right] \\
B^i &= -\kappa \left(\frac{1}{2} \xi^i \bar{\psi}^j \psi^j - \xi^j \bar{\psi}^i \psi^j \right) |w|, \\
\nu &= \xi^i \epsilon^{ij} \left[\psi^j |w| + \frac{i}{2}\kappa^2 \partial_a \{ \gamma^a \psi^j \bar{\psi}^k \psi^k |w| \} \right], \\
\tilde{F}^i &= \frac{1}{\kappa} \xi^i \left\{ |w| + \frac{1}{8}\kappa^3 \partial_a \partial^a (\bar{\psi}^j \psi^j \bar{\psi}^k \psi^k |w|) \right\} - i\kappa \xi^j \partial_a (\bar{\psi}^i \gamma^a \psi^j |w|) \\
&\quad \underline{-\frac{1}{4} e \kappa^2 \xi \xi^i \bar{\psi}^j \psi^j \bar{\psi}^k \psi^k |w|}.
\end{aligned}
\tag{26}
$$

The quartic fermion self-interaction term in $\tilde{F}^i$ is the origin of the local $U(1)$ gauge symmetry of LSUSY.

• **SUSY invariant relations produce a new off-shell commutator algebra which closes on only a translation for all componets of supermultiplets:**

$$[\delta_Q(\zeta_1), \delta_Q(\zeta_2)] = \delta_P(v), \tag{27}$$

where $\delta_P(v)$ **is a translation with a parameter**

$$v^a = 2i(\bar{\zeta}_{1L}\gamma^a\zeta_{2L} - \bar{\zeta}_{1R}\gamma^a\zeta_{2R}) \tag{28}$$

• **Note that the commutator does not induce the U(1) gauge transformation, which is different from the ordinary LSUSY.**

Substituting these SUSY invariant relations into $L_{\rm N=2LSUSYQED}$,
we find NL/L SUSY relations:

$$L_{\rm N=2LSUSYQED} = L_{\rm N=2NLSUSY} + [\text{suface terms}], \ \xi^2 - (\xi^i)^2 = 1. \tag{29}$$

$\Longrightarrow$ **compositeness as eigenstates of space-time symmetry!?**

- **In the local Lorentz frame**
everything appears from the cosmological term of NLSUSYGR action.

- **The direct linearization of highly nonlinear SGM action (12),**
i.e. the construction of an equivalent and renormalizable broken LSUSY field theory defined on the LSUSY supermultiplet of the irreducible representation of SO(N) SP, remains to be carried out.

♣ Systematics of NL/L SUSY relation and $N=2$ SUSY QED:

The SUSY invariant relations

$\Longrightarrow$ **are systematically obtained in the superfield formulation.**

Linearization of NLSUSY in the $d=2$ superfield formulation

- **General scalar superfields are given for the $N=2$ vector supermultiplet by**

$$\mathcal{V}(x,\theta^i) \;=\; C(x) + \bar\theta^i\Lambda^i(x) + \frac{1}{2}\bar\theta^i\theta^j M^{ij}(x) - \frac{1}{2}\bar\theta^i\theta^i M^{jj}(x) + \frac{1}{4}\epsilon^{ij}\bar\theta^i\gamma_5\theta^j\phi(x)$$
$$-\frac{i}{4}\epsilon^{ij}\bar\theta^i\gamma_a\theta^j v^a(x) - \frac{1}{2}\bar\theta^i\theta^i\bar\theta^j\lambda^j(x) - \frac{1}{8}\bar\theta^i\theta^i\bar\theta^j\theta^j D(x), \tag{30}$$

and for the $N=2$ scalar supermultiplet by

$$\Phi^i(x,\theta^i) \;=\; B^i(x) + \bar\theta^i\chi(x) - \epsilon^{ij}\bar\theta^j\nu(x) - \frac{1}{2}\bar\theta^j\theta^j F^i(x) + \bar\theta^i\theta^j F^j(x) - i\bar\theta^i\partial\!\!\!/ B^j(x)\theta^j$$
$$+\frac{i}{2}\bar\theta^j\theta^j(\bar\theta^i\partial\!\!\!/\chi(x) - \epsilon^{ik}\bar\theta^k\partial\!\!\!/\nu(x)) + \frac{1}{8}\bar\theta^j\theta^j\bar\theta^k\theta^k\partial_a\partial^a B^i(x). \tag{31}$$

- **Consider the following NG fermion ψ^i-dependent supertranslations**

$$x'^a = x^a - i\kappa\bar{\theta}^i\gamma^a\psi^i, \quad \theta'^i = \theta^i - \kappa\psi^i, \tag{32}$$

and the corresponding general superfields on (x'^a, θ'^i) and their θ-expansion forms.

$$\tilde{\mathcal{V}}(x^a, \theta^i, \psi^i(x)) = \mathcal{V}(x'^a, \theta'^i), \quad \tilde{\Phi}(x^a, \theta^i, \psi^i(x)) = \Phi(x'^a, \theta'^i). \tag{33}$$

- **Take the hybrid SUSY translations, i.e. LSUSY on x and θ and NLSUSY on λ, e.g.,**

$$\delta_\epsilon\tilde{\mathcal{V}}(x^a, \theta^i, \psi^i(x)) = \mathcal{V}(x'^a + \triangle_\epsilon x'^a, \theta'^i + \triangle_\epsilon\theta'^i) - \mathcal{V}(x'^a, \theta'^i), \tag{34}$$

we find with $\xi_\mu = i\kappa\bar{\epsilon}^i\gamma^a\psi^i$

$$\delta_\epsilon\tilde{\mathcal{V}}(x^a, \theta^i, \psi^i(x)) = \xi_\mu\partial^\mu\tilde{\mathcal{V}}(x^a, \theta^i, \psi^i(x)), \delta\tilde{\Phi}(x^a, \theta^i, \psi^i(x)) = \xi_\mu\partial^\mu\tilde{\Phi}(x^a, \theta^i, \psi^i(x)), \tag{35}$$

i.e., constant components of tilded superfields do not change,SUSY invariant.

• **SUSY invariant constraints of the component fields in $\tilde{\mathcal{V}}$ and $\tilde{\Phi}$,**
i.e., vacuum values of auxiliary fields:

$$\tilde{C} = \tilde{\Lambda}^i = \tilde{M}^{ij} = \tilde{\phi} = \tilde{v}^a = \tilde{\lambda}^i = 0, \tilde{D} = \frac{\xi}{\kappa}, \tilde{B}^i = \tilde{\chi} = \tilde{\nu} = 0, \quad \tilde{F}^i = \frac{\xi^i}{\kappa}, \tag{36}$$

give the abovementioned SUSY invariant relations.

Actions in the $d=2$, $N=2$ NL/L SUSY relation

By changing the integration variables $\underline{(x^a, \theta^i) \to (x'^a, \theta'^i)}$, we can confirm systematically that LSUSY actions reduce to in NLSUSY representation.

(a) The kinetic (free) action with the Fayet-Iliopoulos (FI) D term
for the $N=2$ vector supermultiplet $\mathcal{V}$ reduces to $S_{N=2\mathrm{NLSUSY}}$;

$$S_{\mathcal{V}\mathrm{free}} = \int d^2x \left\{ \int d^2\theta^i \ \frac{1}{32} (\overline{D^i \mathcal{W}^{jk}} D^i \mathcal{W}^{jk} + \overline{D^i \mathcal{W}_5^{jk}} D^i \mathcal{W}_5^{jk}) + \int d^4\theta^i \ \frac{\xi}{2\kappa} \mathcal{V} \right\}_{\theta^i = 0}$$
$$= \xi^2 S_{N=2\mathrm{NLSUSY}}, \tag{37}$$

where

$$\mathcal{W}^{ij} = \bar{D}^i D^j \mathcal{V}, \quad \mathcal{W}_5^{ij} = \bar{D}^i \gamma_5 D^j \mathcal{V}. \tag{38}$$

(Note) The FI D term gives the correct sign of the NLSUSY action.

(b) Yukawa interaction terms for $\mathcal{V}$ vanish,

i.e.

$$\begin{aligned}
S_{\mathcal{V}f} &= \frac{1}{8}\int d^2x \ f \Big[\int d^2\theta^i \ \mathcal{W}^{jk}(\mathcal{W}^{jl}\mathcal{W}^{kl} + \mathcal{W}_5^{jl}\mathcal{W}_5^{kl}) \\
&\quad + \int d\bar\theta^i d\theta^j \ 2\{\mathcal{W}^{ij}(\mathcal{W}^{kl}\mathcal{W}^{kl} + \mathcal{W}_5^{kl}\mathcal{W}_5^{kl}) + \mathcal{W}^{ik}(\mathcal{W}^{jl}\mathcal{W}^{kl} + \mathcal{W}_5^{jl}\mathcal{W}_5^{kl})\} \Big]_{\theta^i=0} \\
&= 0,
\end{aligned} \tag{39}$$

by means of cancellations among four NG-fermion self-interaction terms.

(c) The *most general* **gauge invariant action for $\mathcal{V}$ coupled with Φ^i reduces to $S_{N=2\mathrm{NLSUSY}}$;**

$$\begin{aligned} S_{\mathrm{gauge}} &= -\frac{1}{16}\int d^2x \int d^4\theta^i e^{-4e\mathcal{V}}(\Phi^j)^2 \\ &= -(\xi^i)^2 S_{N=2\mathrm{NLSUSY}}, \end{aligned} \tag{40}$$

————-[some details]—————————

Here the $U(1)$ gauge interaction terms proportional to the gauge coupling constant e becomes four NG-fermion self-interaction terms as

$$S_e(\text{for the minimal off shell multiplet}) = \int d^2x \left\{\frac{1}{4}e\kappa\xi(\xi^i)^2\bar{\psi}^j\psi^j\bar{\psi}^k\psi^k\right\}, \tag{41}$$

which are absorbed in the SUSY invariant relation of the auxiliary field $F^i = F^i(\psi)$ by adding four NG-fermion self-interaction terms as

$$F'^i(\psi) = F^i(\psi) - \frac{1}{4}e\kappa^2\xi\xi^i\bar{\psi}^j\psi^j\bar{\psi}^k\psi^k. \tag{42}$$

Therefore,

under the SUSY invariant relations obtained systematically

the $N=2$ NLSUSY action $S_{N=2\mathrm{NLSUSY}}$ of the flat space-time of SGM action is related to $N=2$ SUSY QED action:

$$S_{N=2\mathrm{NLSUSY}} = S_{N=2\mathrm{SQED}} \equiv S_{\mathcal{V}\mathrm{free}} + S_{\mathcal{V}f} + S_{\mathrm{gauge}} > 0 \tag{43}$$

when $\xi^2 - (\xi^i)^2 = 1$.

$\Longrightarrow$ **NL/L SUSY relation gives the relation between the cosmology and the low energy particle physics in NLSUSY GR.**

- **SGM scenario can predict the magnitude of bare gauge coupling constant.**

For more general SUSY invariant constraints:

$$\tilde{C} = \xi_c, \tilde{\Lambda}^i = \tilde{M}^{ij} = \tilde{\phi} = \tilde{v}^a = \tilde{\lambda}^i = 0, \tilde{D} = \frac{\xi}{\kappa}, \tilde{B}^i = \tilde{\chi} = \tilde{\nu} = 0, \tilde{F}^i = \frac{\xi^i}{\kappa}, \tag{44}$$

NL/L SUSY relation (via the over all normalization factor) gives the magnitude of the bare (dimensionless) gauge coupling constant e

$$e = \frac{\ln(\frac{\xi^{i2}}{\xi^2 - 1})}{4\xi_c}, \tag{45}$$

where ξ**,** ξ^i **and** ξ_c **are vacuum-values (parameters) of auxiliary-fields of the more general off-shell supermultiplet in** $d = 2$**.**

This mechanism is natural and favourable for SGM scenario for unity of nature.

4. Cosmology and Particle Physics in NLSUSY GR

The variation of SGM action $L_{\rm N=2SGM}(e,\psi)$ with respect to ${e^a}_\mu$ gives the equation of motion for ${e^a}_\mu$ in Riemann space-time:

$$R_{\mu\nu}(e) - \frac{1}{2}g_{\mu\nu}R(e) = \frac{8\pi G}{c^4}\{\tilde{T}_{\mu\nu}(e,\psi) - g_{\mu\nu}\frac{c^4\Lambda}{8\pi G}\}, \qquad (46)$$

where $\tilde{T}_{\mu\nu}(e,\psi)$ abbreviates the stress-energy-momentum of superon(NG fermion) including the gravitational interaction.

Note that $-\frac{c^4\Lambda}{8\pi G}$ can be interpreted as the negative energy density of empty space-time, i.e. the dark energy density ρ_D.
The negative sign is unique.

While, we have seen in the preceding section that

$N=2$ **SGM is essentially N=2 NLSUSY action in asymptotic Riemann-flat (tangent) space-time.**

- **The low energy theorem for NLSUSY gives the following superon(massless NG fermion matter)-vacuum coupling**

$$< \psi^j{}_\alpha(q)|J^{k\mu}{}_\beta|0 >= i\sqrt{\frac{c^4\Lambda}{8\pi G}}(\gamma^\mu)_{\alpha\beta}\delta^{jk}, \tag{47}$$

where $J^{k\mu} = i\sqrt{\frac{c^4\Lambda}{8\pi G}}\gamma^\mu\psi^k + \cdots$ **is the conserved supercurrent.**

$\sqrt{\frac{c^4\Lambda}{8\pi G}}$ **is the coupling constant (**g_{sv}**) of superon with the vacuum.**

For extracting the low energy particle physics contents of $N = 2$ SGM (NLSUSY GR) we consider in Riemann-flat asymptotic space-time, where NL/L SUSY relation in flat space-time gives:

$$L_{N=2\mathrm{SGM}} \longrightarrow L_{N=2\mathrm{NLSUSY}} + [\text{suface terms}] = L_{N=2\mathrm{SUSYQED}}. \tag{48}$$

Now we study the vacuum structure of $N = 2$ LSUSY QED action.

- **The vacuum is determined by the minimum of the potential $V(A, \phi, B^i, D)$ of $L_{N=2LSUSYQED}$,**

$$V(A, \phi, B^i, D) = -\frac{1}{2}D^2 + \left\{\frac{\xi}{\kappa} - f(A^2 - \phi^2) + \frac{1}{2}e(B^i)^2\right\} D. \tag{49}$$

• **Substituting the solution of the equation of motion for the auxiliary field D we obtain**

$$V(A,\phi,B^i)=\frac{1}{2}f^2\left\{A^2-\phi^2-\frac{e}{2f}(B^i)^2-\frac{\xi}{f\kappa}\right\}^2+\frac{1}{2}e^2(A^2+\phi^2)(B^i)^2\geq 0. \tag{50}$$

• **The configurations of the fields corresponding to the vacua $V=0$ in (A,ϕ,B^i)-space are classified according to the signatures of the parameters e,f,ξ,κ as follows:**

(I) For $ef>0$, $\frac{\xi}{f\kappa}>0$ case,

$$A^2-\phi^2-(\tilde{B}^i)^2=k^2. \quad \left(\tilde{B}^i=\sqrt{\frac{e}{2f}}B^i,\quad k^2=\frac{\xi}{f\kappa}\right) \tag{51}$$

(II) For $ef<0$, $\frac{\xi}{f\kappa}>0$ case,

$$A^2-\phi^2+(\tilde{B}^i)^2=k^2. \quad \left(\tilde{B}^i=\sqrt{-\frac{e}{2f}}B^i,\quad k^2=\frac{\xi}{f\kappa}\right) \tag{52}$$

(III) For $ef > 0$, $\frac{\xi}{f\kappa} < 0$ case,

$$-A^2 + \phi^2 + (\tilde{B}^i)^2 = k^2. \quad \left(\tilde{B}^i = \sqrt{\frac{e}{2f}} B^i, \quad k^2 = -\frac{\xi}{f\kappa}\right) \tag{53}$$

(IV) For $ef < 0$, $\frac{\xi}{f\kappa} < 0$ case,

$$-A^2 + \phi^2 - (\tilde{B}^i)^2 = k^2. \quad \left(\tilde{B}^i = \sqrt{-\frac{e}{2f}} B^i, \quad k^2 = -\frac{\xi}{f\kappa}\right) \tag{54}$$

• We find that the vacua (I) and (IV) are unphysical, for they produce pathological wrong sign kinetic terms for the fields expanded around the vacuum.

• As for the vacua (II) and (III) we perform similar arguments as shown below and find that two different physical vacua appear.

• The physical particle spectrum is obtained by expanding the fields (A, ϕ, B^i) around the vacuum.

• **Expressions for the case (II):**

Case (IIa)

$$\begin{aligned} A &= (k+\rho)\sin\theta\cosh\omega, \\ \phi &= (k+\rho)\sinh\omega, \\ \tilde{B}^1 &= (k+\rho)\cos\theta\cos\varphi\cosh\omega, \\ \tilde{B}^2 &= (k+\rho)\cos\theta\sin\varphi\cosh\omega \end{aligned}$$

Case (IIb)

$$\begin{aligned} A &= -(k+\rho)\cos\theta\cos\varphi\cosh\omega, \\ \phi &= (k+\rho)\sinh\omega, \\ \tilde{B}^1 &= (k+\rho)\sin\theta\cosh\omega, \\ \tilde{B}^2 &= (k+\rho)\cos\theta\sin\varphi\cosh\omega. \end{aligned}$$

• **For the case (III) the arguments hold by exchanging A and ϕ, called (IIIa) and (IIIb).**

Substituting these expressions into $V(A,\phi,B^i)$ and expanding around the vacuum configuration we obtain the physical particle contents.

• **For the cases (IIa) and (IIIa) we obtain**

$$L_{N=2\mathrm{SUSYQED}} = \frac{1}{2}\{(\partial_a\rho)^2 - 2(-ef)k^2\rho^2\}$$

$$
\begin{aligned}
&+\frac{1}{2}\{(\partial_a\theta)^2+(\partial_a\omega)^2-2(-ef)k^2(\theta^2+\omega^2)\} \\
&+\frac{1}{2}(\partial_a\varphi)^2 \\
&-\frac{1}{4}(F_{ab})^2+(-ef)k^2v_a^2 \\
&+\frac{i}{2}\bar{\lambda}^i\partial\!\!\!/\lambda^i+\frac{i}{2}\bar{\chi}\partial\!\!\!/\chi+\frac{i}{2}\bar{\nu}\partial\!\!\!/\nu+\sqrt{-2ef}(\bar{\lambda}^1\chi-\bar{\lambda}^2\nu)+\cdots,
\end{aligned}
\tag{55}
$$

and the consequent following mass spectra

$$m_\rho^2 = m_\theta^2 = m_\omega^2 = m_{v_a}^2 = 2(-ef)k^2 = -\frac{2\xi e}{\kappa},$$
$$m_{\lambda^i} = m_\chi = m_\nu = m_\varphi = 0. \tag{56}$$

- **The vacuum breaks both SUSY and the local $U(1)$ spontaneously.**

(φ is the NG boson for the spontaneous breaking of $U(1)$ symmetry, i.e. the $U(1)$ phase of B, and totally gauged away by the Higgs-Kibble mechanism with $\Omega(x) = \sqrt{e\kappa/2}\varphi(x)$ for the $U(1)$ gauge (28).)

- **All bosons have the same mass, and remarkably all fermions remain massless.**

- **The off-diagonal mass terms $\sqrt{-2ef}(\bar{\lambda}^1\chi - \bar{\lambda}^2\nu) = \sqrt{-2ef}(\bar{\chi}_{\rm D}\lambda + \bar{\lambda}\chi_{\rm D})$ would induce mixings of fermions. $\Rightarrow$ pathological?**

- **For (IIb) and (IIIb) we obtain**

$$
\begin{aligned}
L_{N=2\mathrm{SUSYQED}} &= \frac{1}{2}\{(\partial_a\rho)^2 - 4f^2k^2\rho^2\} \\
&+\frac{1}{2}\{(\partial_a\theta)^2 + (\partial_a\varphi)^2 - e^2k^2(\theta^2+\varphi^2)\} \\
&+\frac{1}{2}(\partial_a\omega)^2 \\
&-\frac{1}{4}(F_{ab})^2 \\
&+\frac{1}{2}(i\bar{\lambda}^i\partial\!\!\!/\lambda^i - 2fk\bar{\lambda}^i\lambda^i) \\
&+\frac{1}{2}\{i(\bar{\chi}\partial\!\!\!/\chi + \bar{\nu}\partial\!\!\!/\nu) - ek(\bar{\chi}\chi + \bar{\nu}\nu)\} + \cdots .
\end{aligned} \tag{57}
$$

and the following mass spectrum:

$$
\begin{aligned}
& m_\rho^2 = m_{\lambda^i}^2 = 4f^2k^2 = \frac{4\xi f}{\kappa}, \\
& m_\theta^2 = m_\varphi^2 = m_\chi^2 = m_\nu^2 = e^2k^2 = \frac{\xi e^2}{\kappa f}, \\
& m_{v_a} = m_\omega = 0,
\end{aligned} \tag{58}
$$

which can produce mass hierarchy by the factor $\frac{e}{f}$.

- **SUSY is broken spontaneously alone.**

(The massless scalar ω is a NG boson for the degeneracy of the vacuum in $(A, \tilde{B}_2)$-space, which is gauged away provided the gauge symmetry between the vector and the scalar multiplet is introduced.)

- **We have shown explicitly that N=2 LSUSY QED,**

i.e. the matter sector in asymptotic flat-space of $N=2$ SGM, possesses a unique vacuum the type (b).

- **The resulting model describes:**

one charged Dirac fermion ($\psi_D{}^c \sim \chi + i\nu$) with mass $\frac{\xi e^2}{\kappa f}$,
one neutral (Dirac) fermion ($\lambda_D{}^0 \sim \lambda^1 - i\lambda^2$) with mass $\frac{4\xi f}{\kappa}$,
one massless vector (a photon) (v_a),
one charged scalar ($\phi^c \sim \theta + i\varphi$) with mass $\frac{\xi e^2}{\kappa f}$,
one neutral complex scalar ($\phi^0 \sim \rho(+i\omega)$) with mass $\frac{4\xi f}{\kappa}$,
which are the composites of superons.

• **As for cosmological meanings of $N = 2$ LSUSY QED in the SGM scenario, the unique vacuum type (b) may simply explain the observed mysterious (numerical) relations**

$$(energy\ density\ of\ the\ universe)_{obs} \sim (m_\nu)_{obs}{}^4 \sim (10^{-12} GeV)^4 \sim g_{sv}{}^2 \sim \sqrt{\frac{\Lambda}{G}},$$

provided $f\xi \sim O(1)$ and λ^i is identified with neutrino.

• **SGM scenario gives a new insight into the origin of mass. While the vacua of (IIa) and (IIIa) inducing the fermion mixing, unphysical so far, may give new features characteristic of $N = 2$.**

They may be generic for $N > 2$ and deserve further investigations.

5. Summary

NLSUSY GR(SGM) scenario:

- **Ultimate entity for everything,**

New unstable(empty) space-time $[x^a, \psi^N; x^\mu : L_{\rm NLSUSYGR} = L_{\rm EH}(w) - \Lambda]$
NLSUSY GR with Λ for empty space-time
Mach principle is encoded geometrically.

$\Longrightarrow$ **Big Decay (due to false vacuum $\Lambda > 0$)** $\Longrightarrow$

- **Riemann space-time and massless matter**

$[x^a; x^\mu : L_{\rm SGM} = L_{\rm EH}(e) - \Lambda + T(\psi.e)]$
Einstein GR with $\Lambda > 0$ and N superon(SGM),
Phase transition to true vacuum $\Lambda = 0$ realized by copositeness of LSUSY staffs
Superfluidity of space-time and matter, Ignittion of Big Bang, Inflation

$\Longrightarrow$

- **In asymptotic flat space-time, broken N-LSUSY theory emerges from the cosmological term of SGM through NL/L SUSY relation.**

The true vacuum V=0 has promising rich structures, new physics !
Detour of no-go theorem!

Predictions and Conjectures: [Qualitative, accessible ones]

@(Group theory SO(N) sP with $N = \underline{10} = \underline{5} + \underline{5}^*$ of superon-quintet(SQ) hypothesis) :

- Lepton-type spin 3/2 doublet,
- Doubly charged spin 1/2 particles E^{2+},
- Proton is stable due to compositeness,

New wine(superons-quintet) in Old Bottle ($\underline{5}$ of SU(5) GUT)!

@(Field theory via NL/L SUSY relation):

- neutral scalar particle $\sim O(m_\nu)$
- NL/L SUSY relations for N-SUSY $\Longleftrightarrow$ SQ hypothesis for all particles except gravity.

The cosmological constant is the constant for everything!

Many Open Questions ! e.g.,

- d=4 case and the non-Abelian realistic case are urgent.

- Large N case(especially N=5 and N=10), $\cdots$, partial N SUSY breaking?

- Direct linearization of SGM action in curved space-time.
- What is the equivalent LSUSY theory? $\Longleftrightarrow$ superfluidity of nature
- Complete Detour of No-Go Th.! (Massive high-spins in linearized theory)

- Superfield for systematic linearization for $N \geq 2$ interacting cases.

- SGM in extra space-time dimensions $\Longrightarrow$ composite or elementary

- SGM suggests $N \geq 2$ low energy MSSM, SUSY GUT.

- Physical Consequences of spin 3/2 NLSUSY GR.

- equivalence principle and NLSUSYGR.

- Duality and Scale in SGM scenario:

• SGM scenario based on NL space-time symmetry(NLSUSY) elucidates the relation between the high energy superon-graviton(NLSUSY) system and the low energy (LSUSY) system.