Partial Compositness from Partial Unification

By Giacomo Cacciapaglia, SV, Chen Zhang,
arXiv:1911.05454 [hep-ph]

Outline

- Motivation
- Set-up
- Mass generation for 3rd family
- Mass generation for SM Fermions

Motivation

- 2 representations for the HyperColor (HC) group

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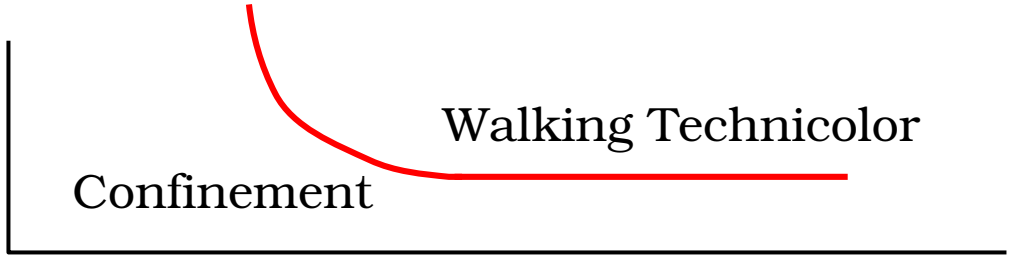
- 

Finite number of solutions

[Belyaev, A., Cacciapaglia, G., Cai, H. et al. J. High Energ. Phys. (2017) 2017: 94.]

Motivation

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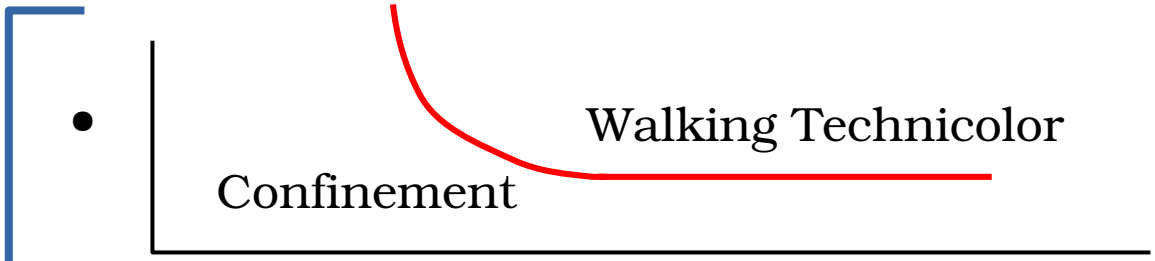
- 

Finite number of solutions

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$G_{\rm HC}$	ψ	χ	Restrictions	$-q_\chi/q_\psi$	Y_χ	Non Conformal	Model Name
	Real	Real	SU(5)/SO(5) × SU(6)/SO(6)				
$SO(N_{\rm HC})$	$5\times\mathbf{S}_2$	$6\times\mathbf{F}$	$N_{\rm HC}\geq 55$	$\frac{5(N_{\rm HC}+2)}{6}$	1/3	/	
$SO(N_{\rm HC})$	$5\times\mathbf{Ad}$	$6\times\mathbf{F}$	$N_{\rm HC}\geq 15$	$\frac{5(N_{\rm HC}-2)}{6}$	1/3	/	
$SO(N_{\rm HC})$	$5\times\mathbf{F}$	$6\times\mathbf{Spin}$	$N_{\rm HC}=7,9$	$\frac{5}{6},\frac{5}{12}$	1/3	$N_{\rm HC}=7,9$	M1, M2
$SO(N_{\rm HC})$	$5\times\mathbf{Spin}$	$6\times\mathbf{F}$	$N_{\rm HC}=7,9$	$\frac{5}{6},\frac{5}{3}$	2/3	$N_{\rm HC}=7,9$	M3, M4
	Real	Pseudo-Real	SU(5)/SO(5) × SU(6)/Sp(6)				
$Sp(2N_{\rm HC})$	$5\times\mathbf{Ad}$	$6\times\mathbf{F}$	$2N_{\rm HC}\geq 12$	$\frac{5(N_{\rm HC}+1)}{3}$	1/3	/	
$Sp(2N_{\rm HC})$	$5\times\mathbf{A}_2$	$6\times\mathbf{F}$	$2N_{\rm HC}\geq 4$	$\frac{5(N_{\rm HC}-1)}{3}$	1/3	$2N_{\rm HC}=4$	M5
$SO(N_{\rm HC})$	$5\times\mathbf{F}$	$6\times\mathbf{Spin}$	$N_{\rm HC}=11,13$	$\frac{5}{24},\frac{5}{48}$	1/3	/	
	Real	Complex	SU(5)/SO(5) × SU(3)^2/SU(3)				
$SU(N_{\rm HC})$	$5\times\mathbf{A}_2$	$3\times(\mathbf{F},\overline{\mathbf{F}})$	$N_{\rm HC}=4$	$\frac{5}{3}$	1/3	$N_{\rm HC}=4$	M6
$SO(N_{\rm HC})$	$5\times\mathbf{F}$	$3\times(\mathbf{Spin},\overline{\mathbf{Spin}})$	$N_{\rm HC}=10,14$	$\frac{5}{12},\frac{5}{48}$	1/3	$N_{\rm HC}=10$	M7
	Pseudo-Real	Real	SU(4)/Sp(4) × SU(6)/SO(6)				
$Sp(2N_{\rm HC})$	$4\times\mathbf{F}$	$6\times\mathbf{A}_2$	$2N_{\rm HC}\leq 36$	$\frac{1}{3(N_{\rm HC}-1)}$	2/3	$2N_{\rm HC}=4$	M8
$SO(N_{\rm HC})$	$4\times\mathbf{Spin}$	$6\times\mathbf{F}$	$N_{\rm HC}=11,13$	$\frac{8}{3},\frac{16}{3}$	2/3	$N_{\rm HC}=11$	M9
	Complex	Real	SU(4)^2/SU(4) × SU(6)/SO(6)				
$SO(N_{\rm HC})$	$4\times(\mathbf{Spin},\overline{\mathbf{Spin}})$	$6\times\mathbf{F}$	$N_{\rm HC}=10$	$\frac{8}{3}$	2/3	$N_{\rm HC}=10$	M10
$SU(N_{\rm HC})$	$4\times(\mathbf{F},\overline{\mathbf{F}})$	$6\times\mathbf{A}_2$	$N_{\rm HC}=4$	$\frac{2}{3}$	2/3	$N_{\rm HC}=4$	M11
	Complex	Complex	SU(4)^2/SU(4) × SU(3)^2/SU(3)				
$SU(N_{\rm HC})$	$4\times(\mathbf{F},\overline{\mathbf{F}})$	$3\times(\mathbf{A}_2,\overline{\mathbf{A}}_2)$	$N_{\rm HC}\geq 5$	$\frac{4}{3(N_{\rm HC}-2)}$	2/3	$N_{\rm HC}=5$	M12
$SU(N_{\rm HC})$	$4\times(\mathbf{F},\overline{\mathbf{F}})$	$3\times(\mathbf{S}_2,\overline{\mathbf{S}}_2)$	$N_{\rm HC}\geq 5$	$\frac{4}{3(N_{\rm HC}+2)}$	2/3	/	
$SU(N_{\rm HC})$	$4\times(\mathbf{A}_2,\overline{\mathbf{A}}_2)$	$3\times(\mathbf{F},\overline{\mathbf{F}})$	$N_{\rm HC}=5$	4	2/3	/	

Motivation

- Top Yukawa coupling $\Rightarrow$ Large anomalous dimension
  Push the scale Λ_F

- UV complete the 4-Fermion Interaction (4-F)

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Historically:

- Extended Technicolor $\rightsquigarrow$ Fail with Flavor
- Bosonic Technicolor $\rightsquigarrow$ Fail with Naturalness

Motivation

- Top Yukawa coupling $\Rightarrow$ Large anomalous dimension

  Push the scale Λ_F

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Historically

Extended Technicolor $\rightsquigarrow$ Fail with Flavor

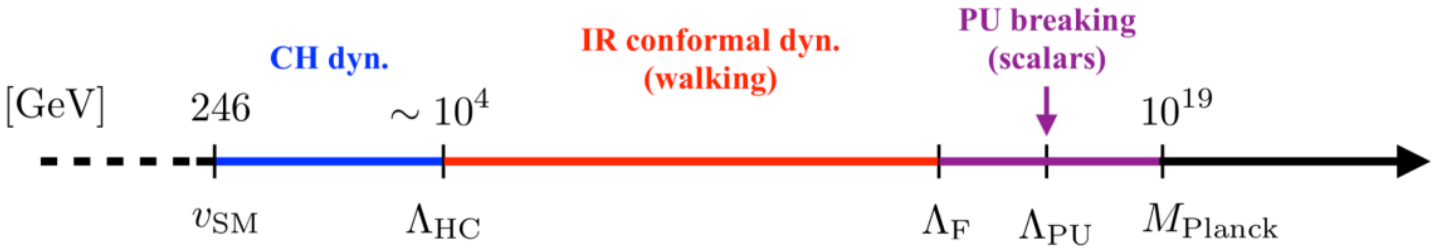
Partial Unification (PU)

Bosonic Technicolor $\rightsquigarrow$ Fail with Naturalness

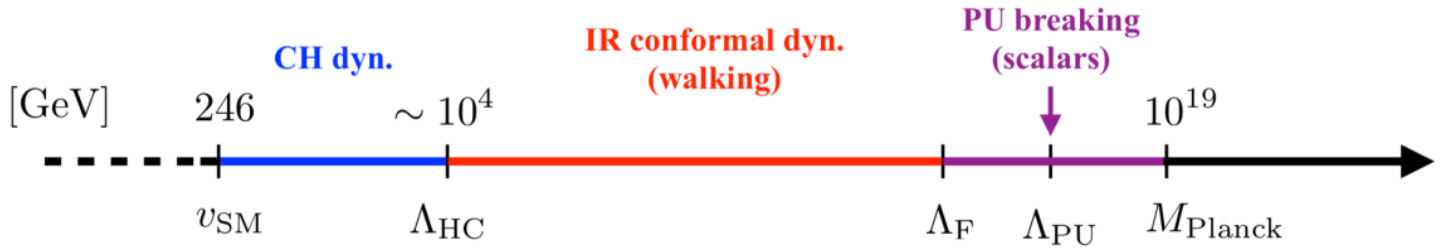
PU

- We partially unify HC and SM
- High scale Scalar to break the gauge group
- 4-F are generated automatically

Set-Up


CH dyn.
IR conformal dyn.
(walking)
PU breaking
(scalars)
[GeV]
246
$\sim 10^4$
10^{19}
$v_{\rm SM}$
$\Lambda_{\rm HC}$
$\Lambda_{\rm F}$
$\Lambda_{\rm PU}$
$M_{\rm Planck}$

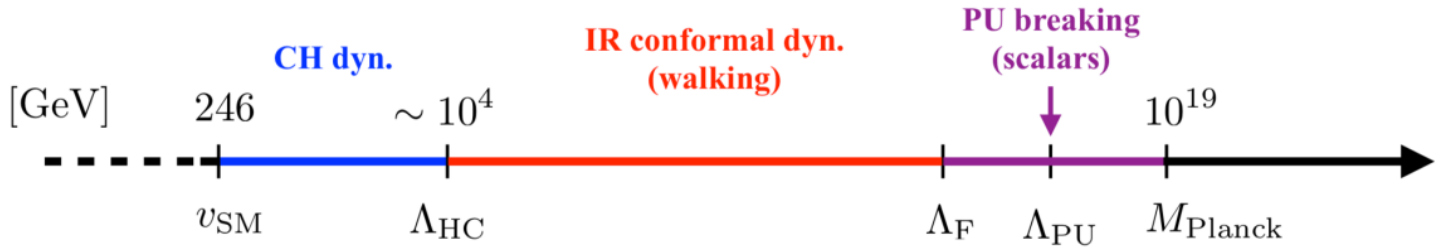
Set-Up



Extended HyperColor Group

$$\left(\begin{array}{c|c} \text{HC} & \\ \hline & \text{QCD} \end{array}\right)$$

Set-Up



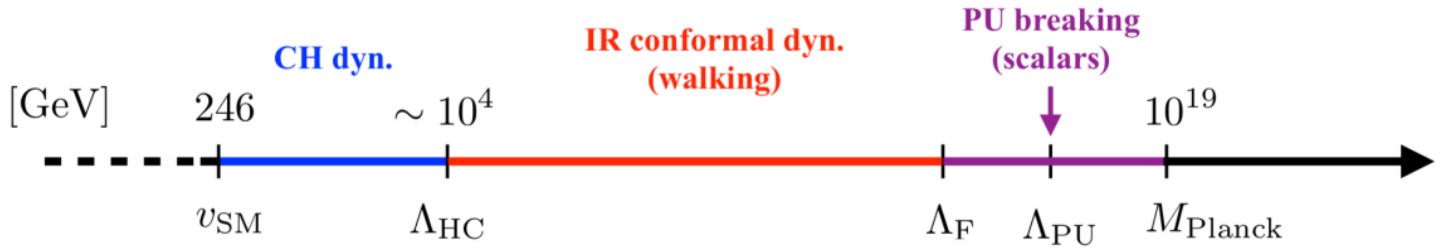
Extended HyperColor Group

$$\left(\begin{array}{c|c} \text{HC} & \\ \hline & \text{QCD} \end{array}\right)$$

$Sp(4)_{HC}$

M8 with at least **4 F** and **6 A** $\Rightarrow$ **Global Symmetry Pattern** $SU(4)/Sp(4)$

Set-Up



Extended HyperColor Group

$$\left(\begin{array}{c|c} \text{HC} & \\ \hline & \text{QCD} \end{array}\right) \Rightarrow SU(7)_{EHC} \times U(1)_E \longrightarrow SU(4)_{CHC} \times SU(3)_c \times U(1)_I$$

$$SU(4)_{CHC} \downarrow Sp(4)_{HC}$$

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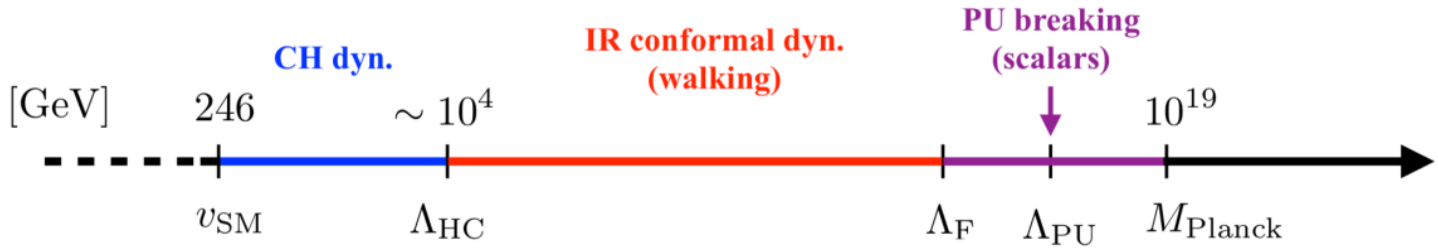

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- Lepton-qark unification : Techni Pati-Salam (TPS) $\boxed{SU(8)_{PS} \times SU(2)_R \times SU(2)_L}$

Set-Up

$$SU(8)_{PS} \times SU(2)_R \times SU(2)_L$$

Step	Breaking Pattern
PS	$SU(8)_{PS} \times SU(2)_R \to SU(7)_{EHC} \times U(1)_E$
EHC	$SU(7)_{EHC} \to SU(4)_{CHC} \times SU(3)_c \times U(1)_X$
CHC	$SU(4)_{CHC} \times U(1)_X \times U(1)_E \to Sp(4)_{HC} \times U(1)_Y$

Fermion Content

Notation : $(4,3)_{1/6} \Rightarrow (Sp(4), SU(3)_c)_{U(1)_Y}$

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	$SU(8)_{PS}$	$SU(2)_R$	$SU(2)_L$
$\Omega^p = \begin{pmatrix} L^p_{u/d} \\ q^p_L \\ l^p_L \end{pmatrix}$	8	1	2

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$\Omega^p = \begin{pmatrix} L^p_{u/d} \\ q^p_L \\ l^p_L \end{pmatrix} \to (4,1)_0$	8	1	2

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$\Upsilon^p = \begin{pmatrix} U_d & D_u \\ d^{c\,p}_R & u^{c\,p}_R \\ e^{c\,p}_R & \nu^{c\,p}_R \end{pmatrix}$	$\bar{8}$	2	1

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$\Xi = \begin{pmatrix} U_u & \chi & \rho & \eta & \omega \\ D_d & \tilde{\chi} & \tilde{\rho} & \tilde{\eta} & \tilde{\omega} \end{pmatrix} \rfloor *$	$70 = A_4$	1	1

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$\Xi = \begin{array}{c} \begin{array}{ccccc} (4,1)_{-1/2} & & (1,1)_0 & & (1,3)_{-1/3} \\ & (5,3)_{-1/3} & & (4,\bar{3})_{-1/6} & \end{array} \\ \begin{pmatrix} U_u & \chi & \rho & \eta & \omega \\ D_d & \tilde{\chi} & \tilde{\rho} & \tilde{\eta} & \tilde{\omega} \end{pmatrix} \end{array} \rfloor *$	$70 = A_4$	1	1

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N^p	1	1	1

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N^p	1	1	1

Scalar Content

	$SU(8)_{PS}$	$SU(2)_R$	$SU(2)_L$	vev
Φ	8	2	1	v^{Φ}_{PS}
Δ	A_3	2	1	v^{Δ}_{EB} v^{Δ}_{CB}
Ψ	Adj	1	1	v^{Ψ}_{EB}
Θ	A_2	1	1	v^{Θ}_{CB}

Scalar Content

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Φ	8	2	1	v_{PS}^{Φ}
Δ	A_3	2	1	v_{EB}^{Δ} v_{CB}^{Δ}
Ψ	Adj	1	1	v_{EB}^{Ψ}
Θ	A_2	1	1	v_{CB}^{Θ}

Break Baryon Number

Techni Pati-Salam for 3rd Family

$$\mathcal{L} = \underset{\text{Gauge}}{\mathcal{L}_G} + \underset{\text{Kinetic}}{\mathcal{L}_F + \mathcal{L}_S} + \underset{\text{Yukawa}}{\mathcal{L}_Y} + \underset{\text{Potential}}{\mathcal{L}_V}$$

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- Minimize $\mathcal{L}_V \Rightarrow$ PS, EHC and CHC breaking
- M_{scalars} and $\Lambda_{CHC} \geq 10^{16} GeV$

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- $$\mathcal{L}_F \supset \begin{array}{l} (\bar{D}^3_u \bar{\sigma}^\mu t^c_R)(\bar{\chi}\bar{\sigma}_\mu \eta), (\bar{U}^3_d \bar{\sigma}^\mu b^c_R)(\bar{\chi}\bar{\sigma}_\mu \eta), (\bar{L}\bar{\sigma}^\mu q_L)(\bar{\eta}\bar{\sigma}_\mu \chi) \\ (\bar{D}^3_u \bar{\sigma}^\mu t^c_R)(\bar{U}_u \bar{\sigma}_\mu \chi), (\bar{U}^3_d \bar{\sigma}^\mu b^c_R)(\bar{U}_u \bar{\sigma}_\mu \chi), (\bar{L}\bar{\sigma}^\mu q_L)(\bar{\chi}\bar{\sigma}_\mu U_u) \\ (\bar{D}^3_u \bar{\sigma}^\mu t^c_R)(\bar{\tilde{\chi}}\bar{\sigma}_\mu D_d), (\bar{U}^3_d \bar{\sigma}^\mu b^c_R)(\bar{\tilde{\chi}}\bar{\sigma}_\mu D_d), (\bar{L}\bar{\sigma}^\mu q_L)(\bar{D}_d \bar{\sigma}_\mu \tilde{\chi}) \\ (\bar{D}^3_u \bar{\sigma}^\mu t^c_R)(\bar{\tilde{\eta}}\bar{\sigma}_\mu \tilde{\chi}), (\bar{U}^3_d \bar{\sigma}^\mu b^c_R)(\bar{\tilde{\eta}}\bar{\sigma}_\mu \tilde{\chi}), (\bar{L}\bar{\sigma}^\mu q_L)(\bar{\tilde{\chi}}\bar{\sigma}_\mu \tilde{\eta}) \\ (\bar{D}^3_u \bar{\sigma}^\mu \nu^c_{\tau R})(\bar{\tilde{\eta}}\bar{\sigma}_\mu \chi), (\bar{U}^3_d \bar{\sigma}^\mu \tau^c_R)(\bar{\tilde{\eta}}\bar{\sigma}_\mu \chi), (\bar{L}\bar{\sigma}^\mu l_L)(\bar{\chi}\bar{\sigma}_\mu \tilde{\eta}) \\ (\bar{D}^3_u \bar{\sigma}^\mu \nu^c_{\tau R})(\bar{\tilde{\chi}}\bar{\sigma}_\mu \eta), (\bar{U}^3_d \bar{\sigma}^\mu \tau^c_R)(\bar{\tilde{\chi}}\bar{\sigma}_\mu \eta), (\bar{L}\bar{\sigma}^\mu l_L)(\bar{\eta}\bar{\sigma}_\mu \tilde{\chi}) \end{array}$$

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4F for **entire** 3rd family

quark $\rightsquigarrow (4,3)_{1/6}$ (EHC)

lepton $\rightsquigarrow (4,1)_{1/2}$ (PS)

$$\downarrow$$

$$\neq t - \tau$$

Techni Pati-Salam for 3rd Family

$$\begin{aligned}\mathcal{L}_Y = &-\mu_N NN - \lambda_\Phi \Upsilon \Phi N - \mu_\Xi \Xi\Xi - \lambda_\Psi \Xi \Psi \Xi \\ &- \lambda_{\Theta L} \Omega \Theta^* \Omega - \lambda_{\Theta R} \Upsilon \Theta \Upsilon - \lambda_\Delta \Upsilon \Delta \Xi + \text{c.c.}\end{aligned}$$

Techni Pati-Salam for 3rd Family

$$\mathcal{L}_Y = -\mu_N NN - \lambda_\Phi \Upsilon \Phi N - \mu_\Xi \Xi\Xi - \lambda_\Psi \Xi\Psi\Xi$$
$$- \lambda_{\Theta L} \Omega\Theta^*\Omega - \lambda_{\Theta R} \Upsilon\Theta\Upsilon - \lambda_\Delta \Upsilon\Delta\Xi + \text{c.c.}$$

Term	1 SM Field	0 SM Field
$\Xi\Psi\Xi$	None	$\chi\eta \Rightarrow (\mathbf{4},\mathbf{1})_{-1/2}$ $\tilde{\chi}\tilde{\eta} \Rightarrow (\mathbf{4},\mathbf{1})_{1/2}$ $U_t D_b \Rightarrow (\mathbf{5},\mathbf{1})_0$, $\chi\tilde{\eta} \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$, $U_t\tilde{\chi} \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$, $\eta\tilde{\chi} \Rightarrow (\mathbf{4},\mathbf{3})_{1/6}$, $\chi D_b \Rightarrow (\mathbf{4},\mathbf{3})_{1/6}$. $\eta\tilde{\eta} \Rightarrow (\mathbf{5},\mathbf{1})_0$.
$\Omega\Theta^*\Omega$	$Lq_L \Rightarrow (\mathbf{4},\mathbf{3})_{1/6}, Ll_L \Rightarrow (\mathbf{4},\mathbf{1})_{-1/2}$.	$LL \Rightarrow (\mathbf{5},\mathbf{1})_0$
$\Upsilon\Theta\Upsilon$	$U_b t_R^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$, $U_b \nu_{\tau R}^c \Rightarrow (\mathbf{4},\mathbf{1})_{1/2}$, $D_t b_R^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$. $D_t \tau_R^c \Rightarrow (\mathbf{4},\mathbf{1})_{1/2}$.	$U_b D_t \Rightarrow (\mathbf{5},\mathbf{1})_0$
$\Upsilon\Delta\Xi$	$\chi b_R^c \Rightarrow (\mathbf{5},\mathbf{1})_0$, $\chi t_R^c \Rightarrow (\mathbf{5},\mathbf{1})_{-1}$, $\eta b_R^c \Rightarrow (\mathbf{4},\mathbf{3})_{1/6}$, $\eta t_R^c \Rightarrow (\mathbf{4},\mathbf{3})_{-5/6}$, $D_b b_R^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{5/6}$, $D_b t_R^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$, $\tilde{\chi} b_R^c \Rightarrow (\mathbf{5},\mathbf{3})_{2/3}$, $\tilde{\chi} t_R^c \Rightarrow (\mathbf{5},\mathbf{3})_{-1/3}$, $\tilde{\eta} b_R^c \Rightarrow (\mathbf{4},\mathbf{1})_{1/2}$. $\tilde{\eta} t_R^c \Rightarrow (\mathbf{4},\mathbf{1})_{-1/2}$. $U_t \tau_R^c \Rightarrow (\mathbf{4},\mathbf{1})_{1/2}$, $U_t \nu_{\tau R}^c \Rightarrow (\mathbf{4},\mathbf{1})_{-1/2}$, $\chi \tau_R^c \Rightarrow (\mathbf{5},\mathbf{3})_{2/3}$, $\chi \nu_{\tau R}^c \Rightarrow (\mathbf{5},\mathbf{3})_{-1/3}$, $\eta \tau_R^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{5/6}$. $\eta \nu_{\tau R}^c \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$.	$U_t U_b \Rightarrow (\mathbf{5},\mathbf{1})_0$, $U_t D_t \Rightarrow (\mathbf{5},\mathbf{1})_{-1}$, $\chi U_b \Rightarrow (\mathbf{4},\mathbf{3})_{1/6}$, $\chi D_t \Rightarrow (\mathbf{4},\mathbf{3})_{-5/6}$, $\tilde{\chi} U_b \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{5/6}$, $\tilde{\chi} D_t \Rightarrow (\mathbf{4},\overline{\mathbf{3}})_{-1/6}$, $\tilde{\eta} U_b \Rightarrow (\mathbf{5},\mathbf{3})_{2/3}$. $\tilde{\eta} D_t \Rightarrow (\mathbf{5},\mathbf{3})_{-1/3}$.

HyperFermion Mass

- Relevant for **HyperColor Dynamic**, low energy **symmetry breaking pattern**

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$$
\begin{array}{cc}
N & \\
\chi & \tilde{\chi} \\
\omega & \tilde{\omega} \\
\eta & \tilde{\eta} \\
\rho & \tilde{\rho} \\
U_u & D_d \\
U_d & D_u \\
L_u & L_d
\end{array}
$$

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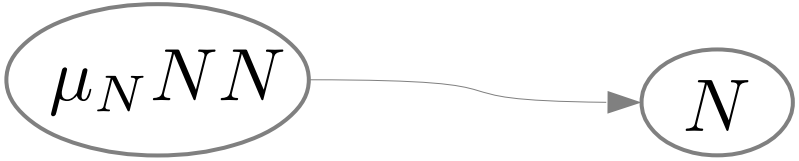

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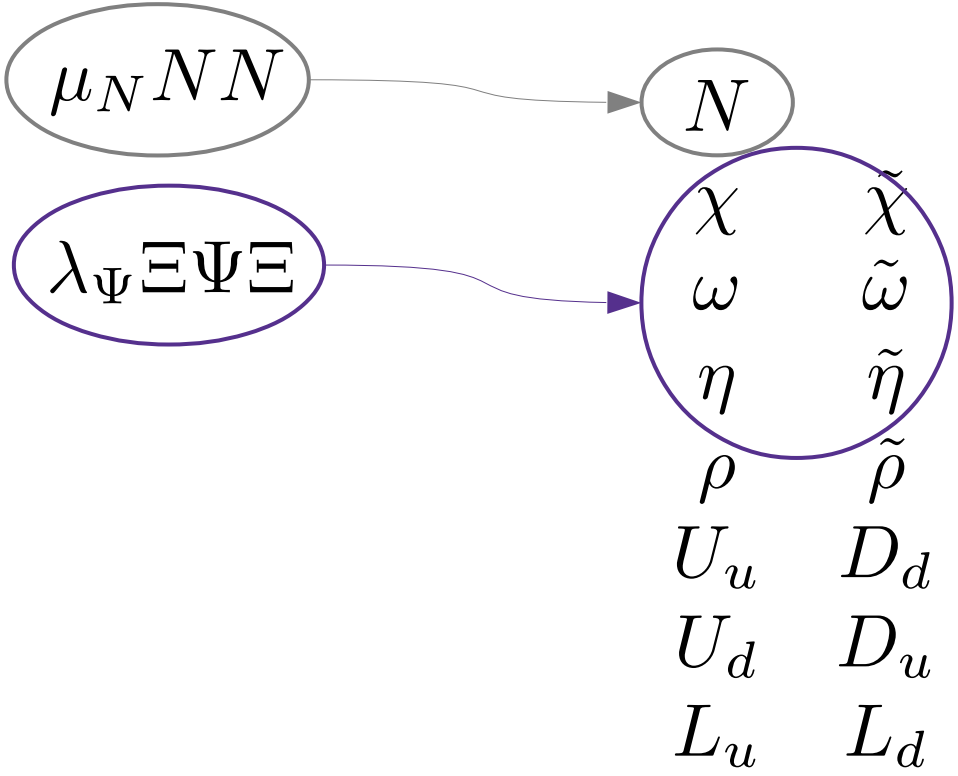

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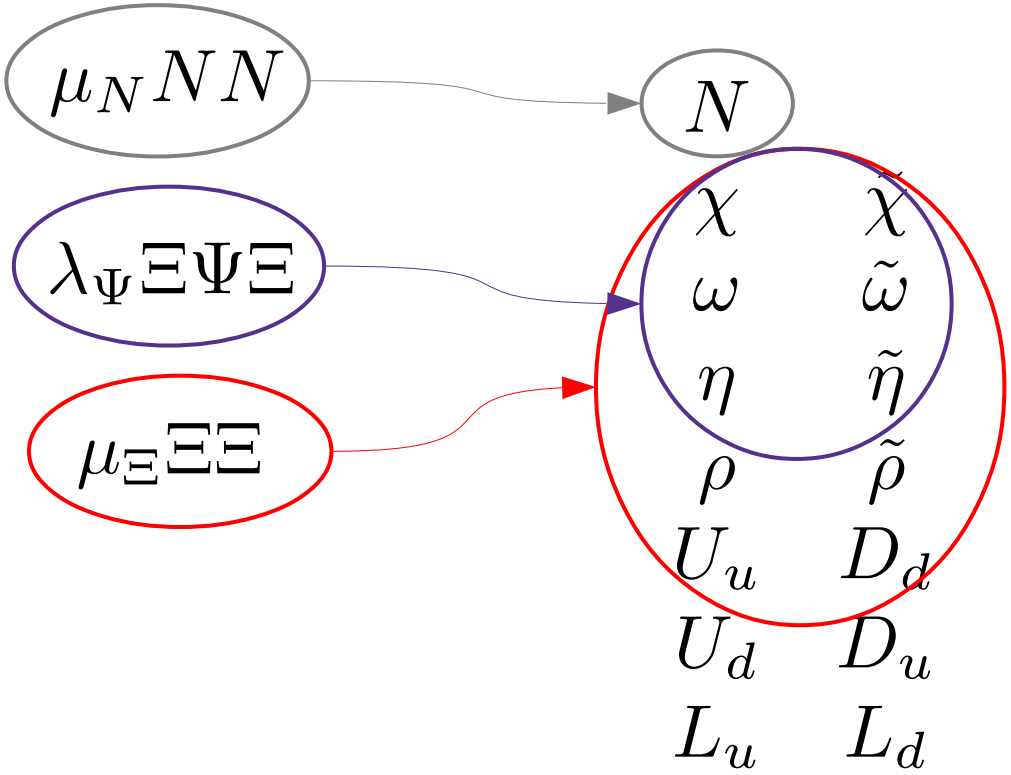

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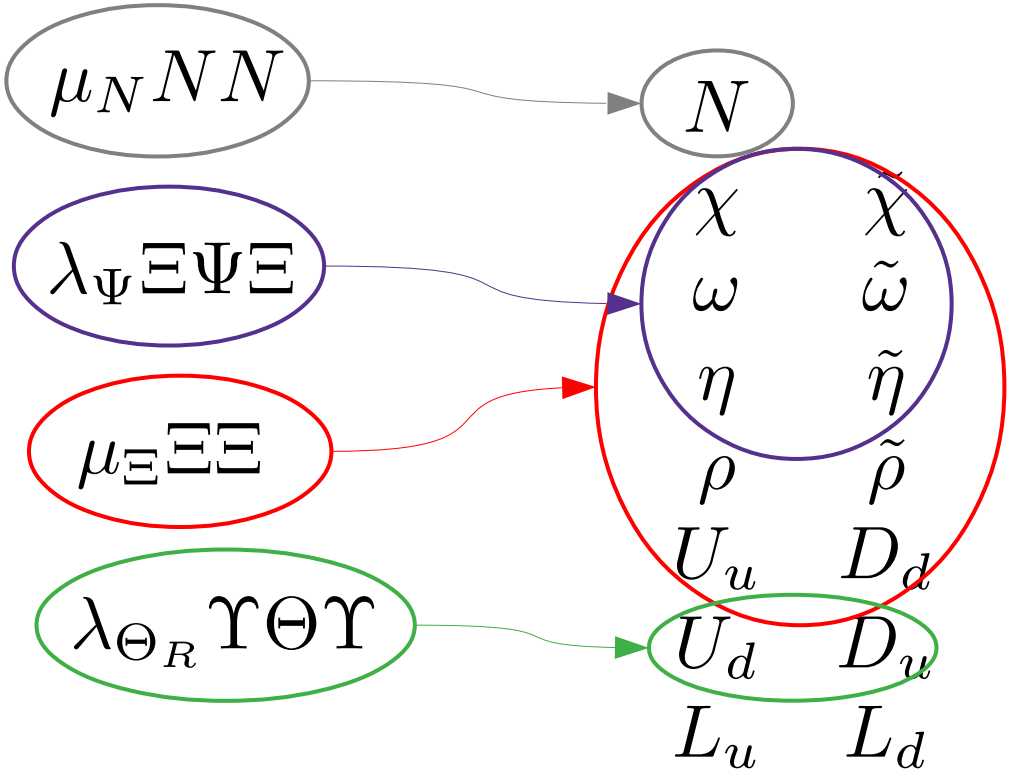

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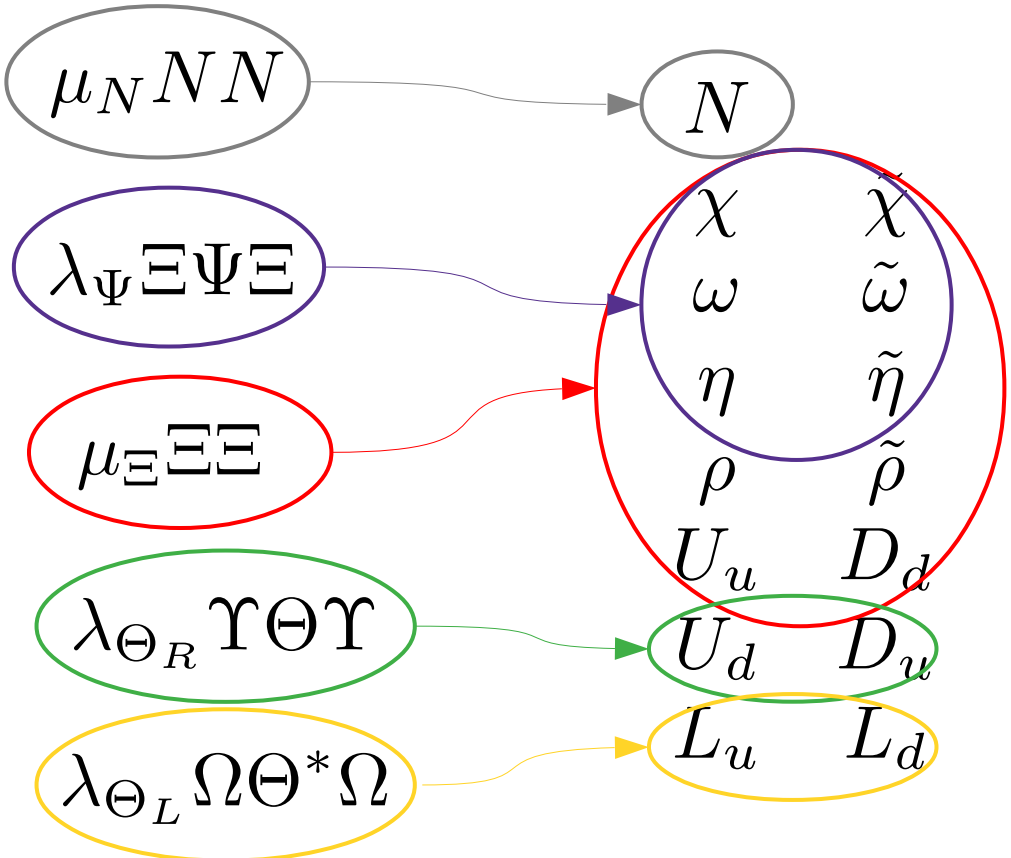

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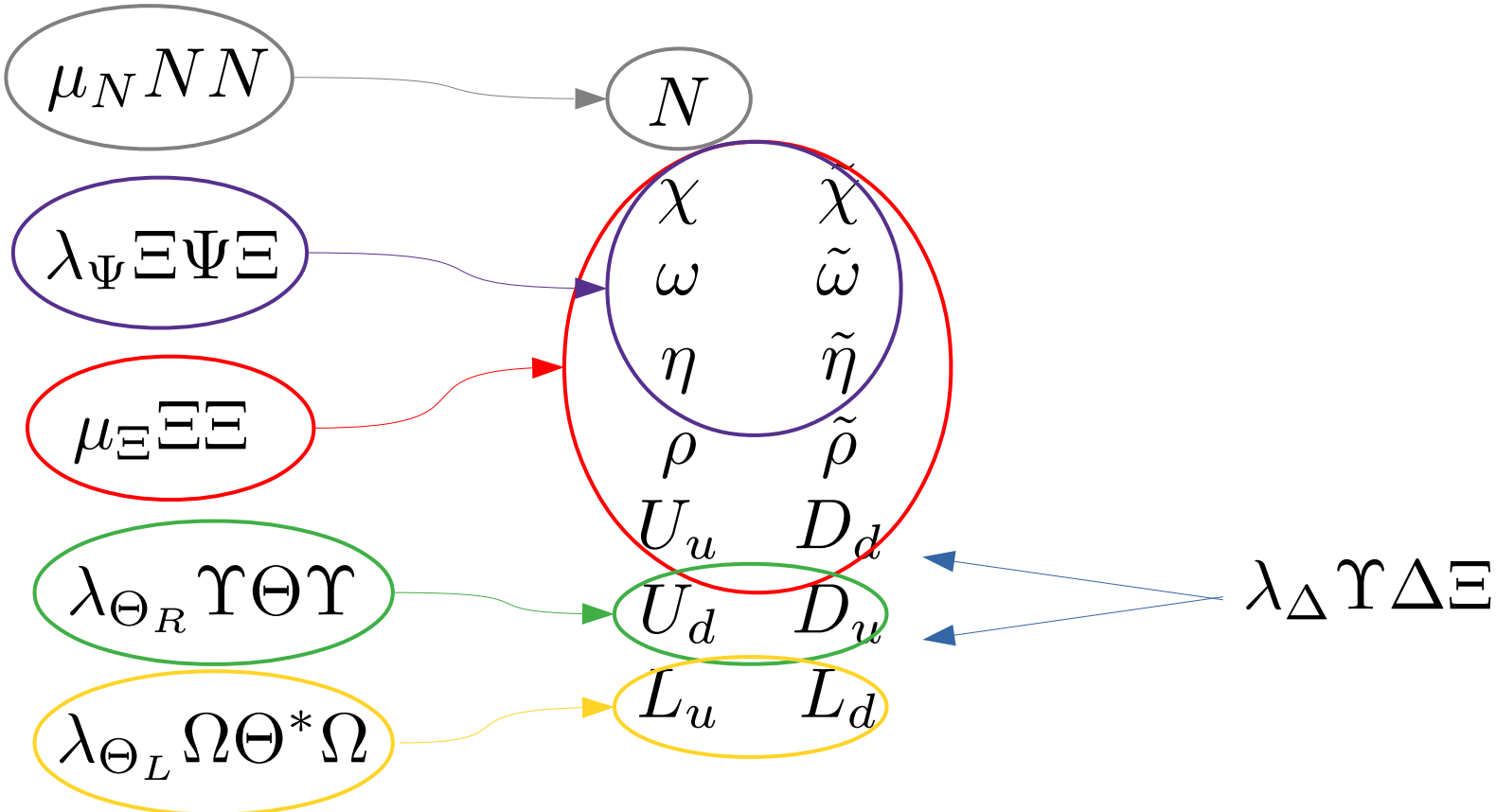

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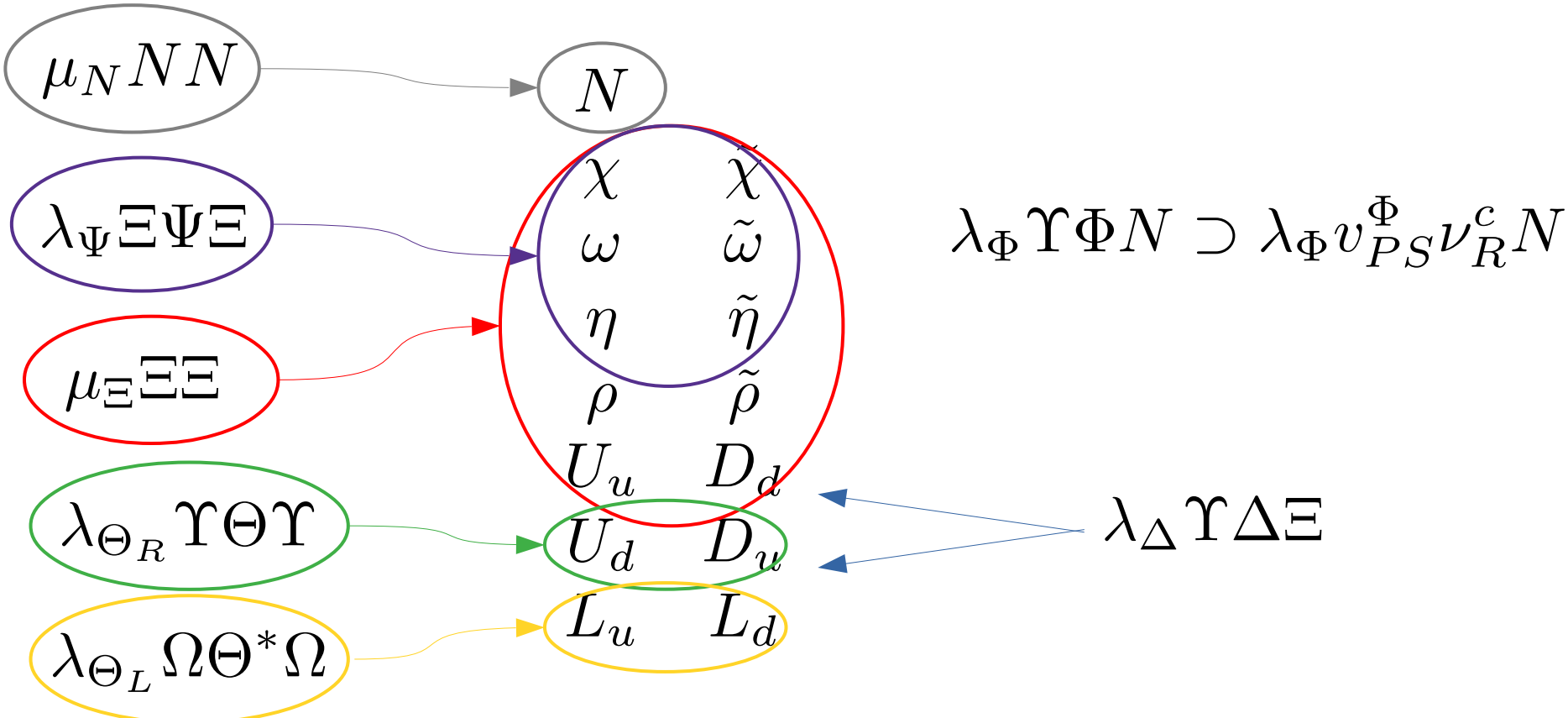

HyperFermion Mass

$$M_{\chi\,\tilde{\chi}} = M_{\omega\,\tilde{\omega}} = a\mu_{\Xi} - b\lambda_{\Psi} v^{\Psi} \qquad \leq \Lambda_{HC}$$

$$M_{\eta\,\tilde{\eta}} = a\mu_{\Xi} + \frac{2b}{5}\lambda_{\Psi} v^{\Psi} \qquad \leq \mathcal{O}(10)\Lambda_{HC}$$

$$M_{\rho\,\tilde{\rho}} = a\mu_{\Xi}$$

$$M_{L_u\,L_d} = 2\lambda_{\Theta_L} v^{\Theta}_{CB} \qquad \leq \Lambda_{HC}$$

HyperFermion Mass

Constraints on the coefficient ! $$|\mu_\Xi| \leq \underbrace{\alpha M_\chi}_{\leq \Lambda_{HC}} + \underbrace{\beta M_\eta}_{\leq \mathcal{O}(10)\Lambda_{HC}}$$

HyperFermion Mass

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$$\Downarrow$$

$$\begin{pmatrix} F_d & G_d \end{pmatrix} \begin{pmatrix} M_F & \\ & M_G \end{pmatrix} \begin{pmatrix} F_u \\ G_u \end{pmatrix} \quad \text{With} \quad M_F \leq M_G$$

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We must assume $M_F \leq \Lambda_{HC}$

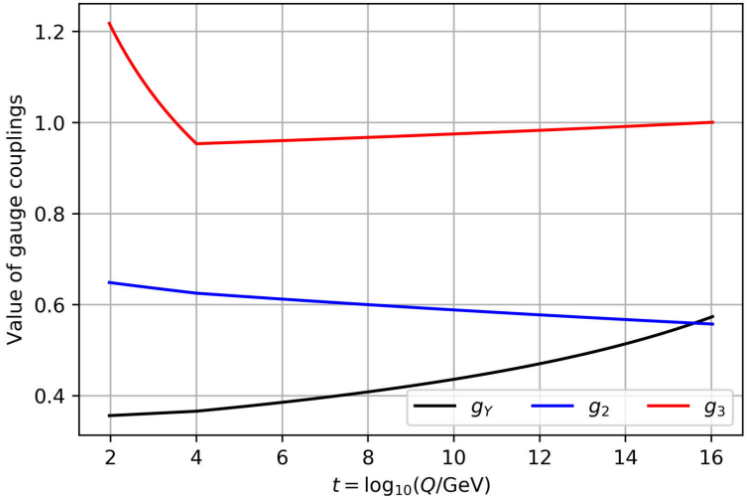
If $M_G \leq \Lambda_{HC}$ we have $SU(6)/Sp(6)$ else $SU(4)/Sp(4)$

HyperColor Dynamic

- **6 A × N_1 F** weyl fermions under **HC** , Asymptotic Freedom if **N_1 < 20**
- We want a **Strongly coupled near Conformal Regime** $[\Lambda_{HC}, \Lambda_{CHC}]$

lower limit for the Conformal Window
- **N_1=10** Schwinger-Dyson
- **N_1=4** Pica-Sannino

- In the TPS **N_1=10/12**



SM Mass Feature

In the SM $\dfrac{m_t}{m_b} \cong 60$

$\rightarrow$ Different running 4F-Operator / Scalar Mediation

---

$m_\tau < m_t$

$\rightarrow$ Massive gauge bosons mediators

$\rightarrow$ 4-F $\supset \eta$, if $M_\eta > \Lambda_{HC}$ there is a suppression

What about neutrinos ?

$$\begin{pmatrix} \nu_L & \nu_R^c & N & \rho & \tilde{\rho} \end{pmatrix} \begin{pmatrix} 0 & \sim m_\tau & 0 & 0 & 0 \\ \sim m_\tau & 0 & \lambda_\Phi v^\Phi & \propto \lambda_\Delta v_{EB}^\Delta & 0 \\ \lambda_\Phi v^\Phi & 0 & \mu_N & 0 & 0 \\ 0 & \propto \lambda_\Delta v_{EB}^\Delta & 0 & 0 & \mu_\Xi \\ 0 & 0 & 0 & \mu_\Xi & 0 \end{pmatrix} \begin{pmatrix} \nu_L \\ \nu_R^c \\ N \\ \rho \\ \tilde{\rho} \end{pmatrix}$$

If $\lambda_\Delta v^\Delta \to 0$ and $\mu_N \ll \lambda_\Phi v^\Phi$ we have an inverse seesaw

To Summarize

- **UV completed the 4F** (with scalars and gauge bosons)
- Generate mass for the **entire family**
- **Mass Hierarchy** between the fermions
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Fermion Content

Notation : $(4,3)_{1/6} \Rightarrow (Sp(4), SU(3)_c)_{U(1)_Y}$

	$SU(8)_{PS}$	$SU(2)_R$	$SU(2)_L$
$\Omega^p = \begin{pmatrix} L^p_{u/d} \\ q^p_L \\ l^p_L \end{pmatrix}$	8	1	2
$\Upsilon^p = \begin{pmatrix} U^p_d & D^p_u \\ d^{c\,p}_R & u^{c\,p}_R \\ e^{c\,p}_R & \nu^{c\,p}_R \end{pmatrix}$	$\bar{8}$	2	1
$\Xi = \begin{pmatrix} U_u & \chi & \rho & \eta & \omega \\ D_d & \tilde{\chi} & \tilde{\rho} & \tilde{\eta} & \tilde{\omega} \end{pmatrix}$	$70 = A_4$	1	1
N^p	1	1	1

Modifications

$$\mathcal{L}_{\rm Yuk} = -\mu_N^{pq}\ N^p N^q - \mu_\Xi\ \Xi\Xi - \lambda_\Psi^\alpha\ \Xi\Psi^\alpha\Xi$$
$$- (\lambda_\Phi^{pq}\Upsilon^p\Phi N^q + \lambda_{\Theta L}^{pq,\alpha}\ \Omega^p\Theta^{\alpha *}\Omega^q + \lambda_{\Theta R}^{pq,\alpha}\ \Upsilon^p\Theta^\alpha\Upsilon^q$$
$$+\lambda_{\Delta R}^p\ \Upsilon^p\Delta_R^*\Xi + \lambda_{\Delta L}^p\ \Omega^p\Delta_L\Xi + \text{h.c.})$$

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Diagonalize μ^{pq} $\lambda_{\Theta_{L/R}}^{pq}$ to get L^p, U_d^p, D_u^p as mass eigenstates

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New Θ field is necessary $\Longrightarrow$ 1st & 2nd to feel EWSB

Can we give mass to 3 generations ?

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$$\begin{pmatrix} \langle O_{R1} O_{L1} \rangle & \langle O_{R1} O_{L2} \rangle & \langle O_{R1} O_{L3} \rangle \\ \langle O_{R2} O_{L1} \rangle & \langle O_{R2} O_{L2} \rangle & \langle O_{R2} O_{L3} \rangle \\ \langle O_{R3} O_{L1} \rangle & \langle O_{R3} O_{L2} \rangle & \langle O_{R3} O_{L3} \rangle \end{pmatrix}$$

need to be rank 3

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need to be rank 3

Gauge and Scalar mediation is not enough

$\Rightarrow$ New Δ $\quad (SU(2)_L)$

What is next ?

- To study the potential in details (U(1) violation)
- Compute the anomaly dimension