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Family Gauge Symmetry From a Composite Model

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ABSTRACT

A family gauge symmetry $SU^F(2)$ could emerge from a composite model of quarks and leptons under some assumptions of chiral hyperflavor symmetry-breaking pattern. Possible dynamical mechanisms which break the family and electroweak gauge group and produce quark-lepton masses are indicated and their phenomenologies are discussed qualitatively.

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The family (or horizontal) gauge symmetry is one of attempts to solve the "generation puzzle" of quarks and leptons [1-4]. However, now what is its origin is still an open problem. The idea about that this symmetry might naturally emerge from a composite model of quarks and leptons certainly is very attractive [1]. But when building a composite model of some reality we must have a few fundamental requirements met by it, for example,

(i) to reproduce the standard model $SU_C(3) \otimes SU_L(2) \otimes U_Y(1)$ or its left-right symmetric generalization $SU_C(3) \otimes SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$ at low (present) energies;

(ii) the 't Hooft anomaly consistency conditions should be subjected if the masslessness of composite fermions (compared to the energy scale Λ_H [5] of the "hypercolor" interaction responsible for binding preons, the constituents, into quarks and leptons) is protected by a continual chiral symmetry;

(iii) a fast proton decay ($\tau p < 10^{31\pm1} y$) should be avoided, etc.

Considering that all of the proposed models so far are tentative, with some successes and some problems, and that it is the case of the model with family gauge symmetry [7], here we are briefly to present a scenario about a composite model (similar to the rishon model, quarks and leptons are three-preon bound states but different from the rishon model, the hypercolor group is $SU_H(4)$), which will show a way that a family gauge group $SU^F(2)$ could emerge quite naturally, moreover, under some choice it is possible to acquire an interesting dynamical mechanism to break the family and electroweak gauge groups and to produce quark-lepton masses.

This model is an extension of the scheme of the three-fermion composite model proposed in the reference [8]. We assume having two kinds of massless preons: "weak" preons V and "family" preons P.[Fl] V form 2 of multiplets $(6,\bar{3})$ and P form n of multiplets (4,3) under the hypercolor and color group $SU_H(4) \otimes SU_C(3)$ respectively. Hence, based on the confinement assumption of the hypercolor, the composite $SU_H(4)$-singlet quarks and leptons are in the configurations (VPP) and (VP^cP^c), where P^c represents the antiparticle of P.

If the rest interactions except the local hypercolor might be switched off, the Lagrangian would have the global symmetry

$$G^0_{HF} = SU_L(12) \otimes SU^F_L(3n) \otimes SU^F_R(3n) \otimes U_P(1) \otimes U_A(1) \qquad (1)$$

where the subgroup $SU_L(12)$ comes from V preons (note that 6 is a real representation of $SU_H(4)$) and the subgroup $SU^F_L(3n) \otimes SU^F_R(3n) \otimes U_p(1)$ comes from P preons. We can arrange the $SU_L(12)$ and $SU^F_{L(R)}(3n)$ fundamental representations W_L and $F_{L(R)}$ respectively as

$$W_L = \begin{pmatrix} (V_L^*)^{i\alpha} \\ (V_L^c)^{j\beta} \end{pmatrix} \quad \begin{matrix} i,j=1,2,3 \\ \alpha,\beta=1,2 \end{matrix} \qquad \text{and } F_{L(R)} = (P^{i\lambda})_{L(R)} \quad \begin{matrix} i=1,2,3 \\ \lambda=1,\ldots,n \end{matrix}$$

where "*" means complex conjugate. In (1) we have considered the instanton effect [10] i.e. the hypercolor instantons have explicitly broken one of the axial U(1) and survived the other $U_A(1)$ in (1) unbroken, because it corresponds to an axial current $2J_\mu^{5F}-J_\mu^{5W_L}$ without anomalous divergence.

Now we assume that the G_{HF}^0 in (1) is spontaneously broken down to its subgroup

$$H_{HF}\otimes Z_4 = SU_C(3)\otimes SU_L(2)\otimes SU_R(2)\otimes SU^F(n)\otimes U_{B-L}(1)\otimes U_{B+L}(1)\otimes Z_4 \tag{3}$$

by the following hypercolor condensate of V and P preons

$$\varepsilon^{ikl}\varepsilon_{imn}\langle(\bar{P}_R)_{k\lambda}(P_L)^{m\lambda}\overline{(i\gamma^2 V_L^c)}_{l\alpha}(V_L^*)^{n\alpha}(\bar{P}_R)_{k'\lambda'}(P_L)^{m'\lambda'}\overline{(i\gamma^2 V_L^c)}_{l'\beta}(V_L^*)^{n'\beta'}\rangle$$
$$\cdot\ \varepsilon^{jk'l'}\varepsilon_{jm'n'}\varepsilon^{\alpha\beta}\varepsilon_{\alpha'\beta'} \neq 0$$
$$i,j,k,l,m,n,k',l',m',n' = 1,2,3;$$
$$\alpha,\beta,\alpha',\beta' = 1,2;\ \lambda,\lambda' = 1,\ldots,n \tag{4}$$

were $i\gamma^2 V_L^c$ is used to replace V_R^* and B=N(V)/6+N(P)/12, L=N(V)/2-N(P)/4 (N(V)--the operator of number of the V preon and N(P)--the operator of number of the P preon).

We note that the color group $SU_C(3)$ has been factorized out. The $H_{HF} \otimes Z_4$ group in (3) contains the desired symmetry $SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$ of the left-right symmetric extension of the standard model with a family group $SU^F(n)$. According to the persistent mass condition [20], masslessness of the composite fermions requires their constituents to keep massless too.[F2] Therefore we prefer assuming the global chiral group $SU_L(2) \otimes SU_R(2)$, coming from V preons, to keep unbroken on the scale Λ_H in order to protect V preons from acquiring masses (we will see later that it will also play a key role to protect some composite fermions (VPP) and (VP^cP^c) from acquiring masses through matching the 't Hooft anomaly consistency conditions). Furthermore, fortunately there is a discrete chiral symmetry Z_4 in (3), which will protect P preons from acquiring masses.

In fact, the $SU^F(n) \otimes Z_4$ in (3) comes from the breakdown of the global chiral group $SU^F_L(n) \otimes SU^F_R(n)$, the residue after factorizing the color group $SU_C(3)$ from $SU^F_L(3n) \otimes SU^F_R(3n)$ in (1). Generally, the group $SU^F_L(n) \otimes SU^F_R(n) \otimes U_P(1)$ contains an axial discrete subgroup $Z^{X_P}_{2n}$ which comes from $U_P(1)$ and the center of one of the two chiral $SU^F_{L,R}(n)$ factors, where the chiral charge X_P is conserved modulo 2n if we define $X_P(P_L)=+1$ and $X_P(P_R)=-1$ for left-handed and right-handed P preons respectively. Because of containing the factor $(\bar{P}_{R\lambda}P^{\lambda}_L)(\bar{P}_{R\lambda'}P^{\lambda'}_L)$ (where the color indices have been omitted) in the condensate (4), it is easy to see that the vector group $SU^F_{L+R}(n) \equiv SU^F(n)$ and the discrete chiral symmetry Z_4 in (3) survived [11]. The Z_4 symmetry will protect P preons from acquiring masses of order Λ_H, as the mass terms of P preons with $X_P = \pm 2$ are ruled out by the Z_4. We note here that the Z_4 does not protect composite fermions (VPP) and (VP^cP^c) from acquiring masses because their mass terms have $X_P = \pm 4$, hence the existence of the Z_4 does not affect on the following results coming from the anomaly consistency equations.

Because the required symmetry Z_4 should be involved in the original symmetry $Z_{2n}^{X_P}$, n can be only an even number.

It is not difficult to see that the $U_A(1)$ in (1) is also broken by the condensate (4) because the condensate (4) has the $U_A(1)$ charge equal to 4,[F3] and that each preon has a definite baryon number B and lepton number L[F4] as $U_B(1)$ and $U_L(1)$ are the linear combination of P preon number $U_P(1)$ and V preon number $U_V(1)$ which is involved in $SU_L(12)$. The representations of preons under the chiral "hyperflavor" group $H_{HF} \otimes Z_4$ are shown in Table 1.

If we compute the β-function of $SU_H(4)$ according to the quantum numbers given in Table 1, we find that the asymptotic freedom constraint of the hypercolor $SU_H(4)$ will limit $n \leq 3$ for the family group $SU^F(n)$. To combine this constraint with that n must be an even number practically leads to the only value of n=2. Later on we will deal with only the case of $SU^F(2)$.

Because of the assumption that the electroweak gauge group $SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$ is not broken by the hypercolor condensate of preons at all, so the hypercolor scale Λ_H in the model should not be connected to weak interaction scale at all. In contrary, the family group $SU^F(2)$ which will eventually be gauged could assumably be broken by the condensate, as a reasonable consequence, the Λ_H should be related to the family gauge interaction scale Λ_F i.e. $\Lambda_F \sim \Lambda_H$. Hence the spontaneous breaking of the family gauge group $SU^F(2)$ could be caused on the scale Λ_H, for example, by the following hypercolor condensates of P preons

$$<(\bar{P}_{Ri1}P_L^{i1})^2> \neq 2<(\bar{P}_{Ri1}P_L^{i1})(\bar{P}_{Ri2}P_L^{j2})> \neq <(\bar{P}_{Ri2}P_L^{i2})^2> \neq 0$$

$$i,j = 1,2,3, \qquad (5)$$

and the 3 family gauge bosons will thus acquire masses of order $m_F \sim \Lambda_F \sim \Lambda_H$. Based on the analyses of rate for rare processes [3], the lower bounds for m_F must lie in the 10-100 TeV region. This means that we must have $\Lambda_H \sim \Lambda_F \gtrsim 10\text{-}100$ TeV in the model. As far as the chiral symmetry-breaking caused by the condensate (4) is concerned, its symmetry-breaking scale Λ_{HF} might be $\Lambda_{HF} \gtrsim \Lambda_H$ on the basis of some conjecture from the recent research results of lattice gauge theory [12].

The spontaneous breakdown of the global group G^0_{HF} in (1) to the group $H_{HF} \otimes Z_4$ in (3) will be accompanied with appearance of 196 goldstone bosons, corresponding to the

The spontaneous breakdown of the global group G_{HF}^{0} in (1) to the group $H_{HF} \otimes Z_4$ in (3) will be accompanied with appearance of 196 goldstone bosons, corresponding to the number of the broken generators of G_{HF}^{0}. However, it can be shown [9] that most of these bosons become pseudogoldstones with masses of order 1~3 TeV when color, electroweak and family gauge interactions are turned on and the goldstone boson connected to the breaking of the $U_A(1)$ will be an invisible axion. Therefore, the appearance of these goldstone bosons does not affect low energy phenomenology.

Now we can discuss the anomaly consistency conditions based on the unbroken chiral hyperflavor group $H_{HF} \otimes Z_4$ assumed up to now.[F5] The H_{HF}-representations of the composite fermions as $SU_H(4)$-singlets are listed in Table 2.

Following 't Hooft [6], we specify an index for each representation. The anomalies come from the three-point functions $[SU_L(2)]^2\, U_{B\pm L}(1)$. Taking n=2, we obtain the following two anomaly consistency equations:

$$3(l_{1+} \pm q_{1+} + 8l_{2+} + 10l_{3+} \pm 2q_{2+} \pm 5q_{3+})$$

$$+ (l_{1-} \pm q_{1-} + 8l_{2-} + 10l_{3-} \pm 2q_{2-} \pm 5q_{3-}) = \begin{cases} 12 & (6) \\ 6 & (7) \end{cases}$$

In general speaking, there will be some non-physical solutions because the anomaly consistency equations are necessary but not sufficient conditions of keeping composite fermions massless. Thus we have to seek more constraints in order to obtain the possible physical solution. The term "possible" means that at least it will illuminate some interesting scenario although it has not yet been proven.

Hence we can assume that a realistic solution will have

$$|q_i|=|l_i| \tag{8}$$

and/or

$$|q_i|\leq|,|l_i|\leq| \tag{9}$$

(8) implies that the quark and lepton generations in nature may have one-to-one correspondence, and (9) is what of following reference [7].

However it is found that if simultaneously considering the two anomaly consistency equations (6) and (7) we could not be led to any satisfactory solutions. For instance, when excluding exotic colored fermions and considering the constraint (8) but the (9) only for $SU^F(2)$-nonsinglet indices, we have the solution

$$A: l_{1+}=-q_{1+}=1 \text{ (triplet)}, \ l_{1-}=q_{1-}=6 \text{ (singlet)}$$

and the rest indices are equal to zeros.

In the above parentheses the corresponding $SU^F(2)$-representations are indicated. The solution A contains 9 generations, in fact, that not only conflicts with the Big Bang theory of cosmology (the number of neutrino species $n_\nu\leq 4$ [19] according to the prediction of the Big Bang theory) but also has some trouble with the 6 generations belonging to $SU^F(2)$-singlets for distinguishing them. When exotic colored fermions are allowed and both (8) and (9) are taken into account the situation becomes worse. Therefore, this causes us to consider another case in which the global subgroup $U_{B+L}(1)$ in (3) is broken spontaneously on the scale Λ_H.

From the requirement of phenomenology, the breakdown of $U_{B+L}(1)$ must not affect on the desired gauge symmetry $SU_C(3) \otimes SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1) \otimes SU^F(2)$ and avoid "fast" proton decay and strong coupling of the induced goldstone boson with the rest particles. In fact, the hypercolor condensate which breaks $U_{B+L}(1)$ but keeps the symmetry $SU_C(3) \otimes SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1) \otimes SU^F(2)$ must be

$$\varepsilon_{\alpha\gamma}\varepsilon_{\beta\delta} < (\bar{V}_L)^{i\alpha} (i\gamma^2 V_L^*)^{j\beta} (\bar{V}_L)^{k\gamma} (i\gamma^2 V_L^*)^{l\delta} (\bar{P}_R)_{i\lambda} (P_L^c)_{j\rho} (\bar{P}_R)_{k\lambda'} (P_L^c)_{l\rho'} >$$

$$\varepsilon^{\lambda\rho}\varepsilon^{\lambda'\rho'} \neq 0 \qquad (10)$$

We see from Table 1 that the 8-fermion condensate $((\bar{V}V^c)^2(\bar{P}P^c)^2)$ in (10) has B=L=-1, hence it gives rise to the processes of $\Delta(B+L)=2$ such as $uu \to d^c e^+$ etc. Obviously the effective coupling responsible for the change of B+L is roughly proportional to $1/\Lambda_H^8$ [13]. When $\Lambda_H \gtrsim 10 \sim 100$ TeV this coupling will predict proton lifetime $\tau_p > 6 \times (10^{32}-10^{48})$ years, which does not conflict with the present experimental data [14,22].

The goldstone boson ϕ produced by the spontaneous breaking of the $U_{B+L}(1)$ is coupled to matter with an effective coupling $\phi lqqq$. The effective coupling constant $g_{\phi-lqqq}$ is proportional to m_q/Λ_H^4, where we have used the general result that, at tree level, a goldstone boson has only derivative couplings with fermions thus the coupling constant has order m_f/Λ_H (if Yukawa coupling) or m_f/Λ_H^4 (if a coupling such as $\phi lqqq$) where m_f is the fermion mass [15]. Because of the smallness of m_q ($m_q/\Lambda_H<<1$ when $m_q=m_u$ or m_d) $g_{\phi-lqqq}$ is very weak so that the goldstone boson is practically invisible.

So far we come to the case that $U_{B+L}(1)$ is broken without any consequences forbidden by phenomenology and $U_{B-L}(1)$ survives, therefore the anomaly consistency conditions turn to the equation (7) only now. If we are confined to the case that the asymptotic freedom of QCD at the composite level is kept or has only small violation at the high energies near Λ_H, the several simple solutions of equation (7) with the conditions (8) and (9) are

B:# $l_{1+}=-q_{1+}=1$ (triplet)

C:# $l_{1+}=-q_{1+}=1$ (triplet), $l_{1-}= q_{1-}= 1$ (singlet)

D:# $l_{1+}= q_{1+}=1$ (triplet), $l_{1-}=-q_{1-}=-1$ (singlet), $l_{2-}=1$ (singlet)

E:# $l_{1+}= q_{1+}=1$ (triplet), $l_{2-}= q_{2-}= 1$ (singlet)

and the rest indices are zeros for each solution (B,C,D and

E).

The solutions B and C correspond to the cases of three and four generations of quarks and leptons respectively without exotics. In these cases the dynamical breaking of the electroweak gauge group $SU_L(2) \otimes SU_R(2 \otimes U_{B-L}(1)$ (when we switch it on) will be a problem, so some new mechanism is needed, for instance it may be realized by introducing a technicolor force with energy scale $\Lambda_{TC} \sim 1$ TeV and technifermions belonging to the fundamental representations of the technicolor group G_{TC}, $SU_H(4)$-singlets and the same representations as quarks and leptons under the subgroup $SU_C(3) \otimes SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$. It is no doubt that this mechanism works [16] but it is not absorbing as the relation between the hypercolor and the technicolor is trivial.

A more interesting case is the solution D. It contains one generation of color 8-plet lepton l_8 as well as four generations of the ordinary quarks q and leptons l. The existence of l_8 make it possible that the color condensates of $l_{8L}\bar{l}_{8R}(\phi_8)$, $\bar{l}_{8L}l^c_{8R}(\Delta_L)$ and $\bar{l}_{8R}l^c_{8L}(\Delta_R)$ [23] will break dynamically the electroweak gauge group $SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$ and parity such as the technicolor condensates in the technicolor theory [16], because the color force between exotic leptons l_8 might be stronger than ordinary quarks q thus the mass scale Λ_{C_8} of the chiral symmetry-breaking in l_8 sector could be up to ~ 1 TeV. This mechanism was first proposed by Marciano [17] and seems to be supported by recent Monte Carlo study on lattice gauge be supported by recent Monte Carlo study on lattice gauge theory by Kogut and others [12]. We also note that there could be the effective interactions like $(g_{\sigma\tau}/\Lambda_H^2)\bar{q}^{\sigma} l_8 \bar{l}_8 q^{\tau}$ (σ,τ are family indices and the similar couplings are valid to leptons), then with the color condensates $\langle l_8\bar{l}_8\rangle \sim \Lambda_{C8}^3 \sim (1\ \mathrm{TeV})^3$, we can obtain quark and leptons masses of order $\propto \Lambda_{C_8}^3/\Lambda_H^2$. This is just the mass generation mechanism suggested by by E. Guadagmini, K. Konishi, P. Sikivie and J. Preskill [18]. Moreover, we can reasonably attribute the interfamily splitting to the different effective coupling constants $g_{\sigma\tau}$, a natural consequence of breaking of the family group $SU^F(2)$ on the mass scale Λ_H, and the large Majorana masses of the right-handed neutrinos and the small masses of the left-handed neutrinos to the effect of color condensate $\langle \bar{l}_{8R} l^c_{8L}\rangle$ [23]. With the help of this mechanism and the self-energies of the various interactions in this model, it is hoped to obtain correct masses of quarks q, leptons l and l_8.

The similar mechanism arise also from the solution E which contains one generation of color 6-plet quarks q_6 and 8-plet leptons l_8 as well as three generations of q and l, thus we will have another scalar color condensate of $q_{6L}\bar{q}_{6R}(\phi_6)$ added to those formed by l_{8L} and l_{8R}. However, this only slightly complicates the scenario technically.

If the above mechanism is true, the most characteristic is that the lifetimes of the weak interaction bosons $W^+_{L,R}$, $W^-_{L,R}$ and $Z^0_{1,2}$ will be shorten because the weak interaction bosons could decay to $l_8,\bar{l}_8$ and/or $q_6,\bar{q}_6$ as well as $q,\bar{q}$ and $l,\bar{l}$ if their masses are greater than $m_{l_8}+m_{\bar{l}_8}$ and/or $m_{q_6}+m_{\bar{q}_6}$ in addition to the exotic quark-lepton physics.[F6] Finally we note that there exists universality of the weak interaction because we have accepted the scheme of the $SU_L(2) \otimes SU_R(2) \otimes U_{B-L}(1)$ gauged. We will discuss these and the masses of q,l,l_8 and/or q_6 in detail in another paper.

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FOOTNOTES

[F1] Weak gauge interaction will be carried by V-preons and family gauge interaction will be carried by P-preons and that is the reason why we name them weak-preons and family-preons.

[F2] S. Dimopoulos et al. argued that this condition may be loosen [21]: provided the constituents' masses are less than a certain critical mass m_c it is possible to obtain massless composite fermions. But it does not influence our discussions.

[F3] As a result of this breakdown, we have a discrete chiral Z_4' symmetry left too. However the mass terms of P preons have $U_A(1)$ charge equal to ± 4 occasionally thus the Z_4' does not protect the P preons from acquiring masses.

[F4] If we take the "economic principle" [7], i.e. the massless composite fermions are in those configurations containing only three "valence" preons, then such color triplets and color singlets as (3V+2P)(B=2/3,L=1) and (5V+4P)(B=7/6,L=3/2) (refer to Table 1) which have exotic B- and L- number will be excluded out of the massless composite fermions.

[F5] In spite of the fact that the family gauge group $SU^F(2)$ has been broken on the scale Λ_H we have still included it in H_{HF} so as to classify generations of massless composite fermions according to $SU^F(2)$ representations.

[F6]The exotic quark-lepton physics means all of the phenomena such as exotic baryons and mesons, hidden exotic mesons e.g. $q_6\bar{q}_6$, $l_8\bar{l}_8$ boundstates, the production of the exotic quarks $q_6(\bar{q}_6)$ and leptons $l_8(\bar{l}_8)$ by photon, weak interaction bosons and gluons etc.

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Table 1 The $H_{HF} \otimes Z_4$ representations of chiral preons.

	$SU_H(4)$	$SU_C(3)$	$SU_L(2)$	$SU_R(2)$	$SU^F(n)$	$U_{B-L}(1)$	$U_{B+L}(1)$	$Z_4(Xp)$
V_L	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	$\square$	1	1	$-1/3$	$2/3$	0
V_R	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	$\begin{smallmatrix}\square\\\square\end{smallmatrix}$	1	$\square$	1	$-1/3$	$2/3$	0
P_L	$\square$	$\square$	1	1	$\square$	$+1/3$	$-1/6$	1
P_R	$\square$	$\square$	1	1	$\square$	$+1/3$	$-1/6$	-1

Table 2 The represention and indices of composite fermions under group H_{HF}
(The suffix "+" and "−" in an index refer to the representations $\yng(2)$ (or $\overline{\yng(2)}$) and $\yng(1,1)$ (or $\overline{\yng(1,1)}$) of $SU^F(n)$ respectively)

(VPP)	$B-L=B+L=1/3$	(VP^cP^c)	$B-L=-1,\ B+L=+1$
$(\yng(1),\yng(1),1,\yng(2)+\yng(1,1))q_{1\pm}$	$(\yng(1),1,\yng(1),\yng(2)+\yng(1,1))\text{-}q_{1\pm}$	$(1,\yng(1),1,\overline{\yng(2)}+\overline{\yng(1,1)})\ell_{1\pm}$	$(1,1,\yng(1),\overline{\yng(2)}+\overline{\yng(1,1)})\text{-}\ell_{1\pm}$
$(\yng(2,2),\yng(1),1,\yng(2)+\yng(1,1))q_{2\pm}$	$(\yng(2,2),1,\yng(1),\yng(2)+\yng(1,1))\text{-}q_{2\pm}$	$(\yng(2,1),\yng(1),1,\overline{\yng(2)}+\overline{\yng(1,1)})\ell_{2\pm}$	$(\yng(2,1),1,\yng(1),\overline{\yng(2)}+\overline{\yng(1,1)})\text{-}\ell_{2\pm}$
$(\yng(3,2),\yng(1),1,\yng(2)+\yng(1,1))q_{3\pm}$	$(\yng(3,2),1,\yng(1),\yng(2)+\yng(1,1))\text{-}q_{3\pm}$	$(\yng(3,3),\yng(1),1,\overline{\yng(2)}+\overline{\yng(1,1)})\ell_{3\pm}$	$(\yng(3,3),1,\yng(1),\overline{\yng(2)}+\overline{\yng(1,1)})\text{-}\ell_{3\pm}$