We investigate the 35-plet baryons from the chiral soliton models. We find that the coupling constant for the decay of 35-plet baryons with spin 3/2 to the decuplet baryons is surprisingly small, but that for the decay to 27-plet baryons with spin 3/2 is larger. We give all the masses and widths of 35-plet baryons with spin 5/2 and suggest candidates for all nonexotic members from the available particle listings. We also focus on $\Delta_{5/2}$ and $\Theta_2$, which are the lightest two baryons of 35-plet with spin 5/2 and with simplest minimal pentaquark configurations. Calculations show that $\Gamma_{\Delta_{5/2}} < 380$ MeV, compared with the results from $SU(2)$ Skyrme Model ($\Gamma_{\Delta_{5/2}} > 800$ MeV), and $\Gamma_{\Theta_2} < 100$ MeV if we assume that their widths are dominated by two-body decay and that $\Theta^+$ has a width $\Gamma_{\Theta^+} < 25$ MeV.

I. INTRODUCTION

Chiral soliton models, based on chiral symmetry and large $N_c$ limit QCD, has played a crucial role in the observations of an exotic baryon with a narrow width and a positive strangeness number $S=+1$, a possible candidate for $\Theta^+$ with minimal pentaquark configuration $|uudq\bar{c}\rangle$, which is the lightest member of the antidecuplet, predicted from chiral soliton models (Skyrme model and chiral quark-soliton model) \cite{1,2,3,4,5,6,7}. In chiral soliton models, the generalization of $SU(2)$ collective quantization to the $SU(3)$ case, taken into considerations the chiral symmetry breaking terms, can indeed give the experimentally agreeable mass splitting between the octet and the decuplet baryions \cite{8,9,10,11,12,13}. The antidecuplet with spin 1/2, pointed out by Manohar \cite{8} and Chemtob \cite{9}, is the third baryon multiplet, besides the octet and the decuplet, which we have been familiar with for a long time. By identifying $N(1710)$ as a known member, Diakonov, Petrov, and Polyakov \cite{12} calculated both the masses and the widths of the antidecuplet baryons from chiral soliton models, among which the lightest member $\Theta^+$ was predicted to have a mass $1530$ MeV and a narrow width $\Gamma_{\Theta^+} < 30$ MeV \cite{13}, which agree surprisingly with experimental results.

Based on the large $N_c$ analysis, the mass difference between the antidecuplet and the octet in the $SU(3)$ chiral symmetry limit is of $O(1)$, which seems to invalidate the collective quantization and the spurious prediction of $\Theta^+$ from chiral soliton models \cite{15}. However, by introducing “exotiness” $X$, the minimal number of additional quark-antiquark pairs needed to construct a multiplet on top of the usual $N_c$ quarks, Diakonov and Petrov \cite{16} showed that the collective quantization description fails only when the exotiness becomes comparable to $N_c$ and that in the case of the antidecuplet the exotiness is 1, which is in favor of the collective quantization. Moreover, under large $N_c$ limit, the width of $\Theta^+$ is $1/N_c$ suppressed with respect to $\Delta$ \cite{20}, which explains why $\Theta^+$ has so narrow a width compared with other ordinary baryons from the point of view of chiral soliton models.

In chiral soliton models, the allowed baryon multiplets are those satisfying $I = J$ for hypercharge $Y = 1$ baryons. Under such a constraint, the baryon multiplets with exotiness $= 1$, besides the antidecuplet with spin 1/2, are 27-plets with spin 3/2 and 1/2 and 35-plets with spin 5/2 and 3/2, which, in the quark language, are of the minimal five-quark configuration, i.e., so-called pentaquark states. In Refs. \cite{21,22,23,24,25,26}, the properties of those baryons were also discussed, and in Ref. \cite{22} it has been found surprisingly that all the nonexotic members of the 27-plet with spin 3/2 can be identified from the available baryon listings \cite{27}, agreeable with experiments both in mass and width.

Because $J = \frac{5}{2}$ is comparable with $N_c = 3$, in the $SU(2)$ Skyrme model, the higher-spin baryons $(I = J \geq 5/2)$ have so large angular velocities that strong $\pi$ radiation will cause them to possess a width $\Gamma > 800$ MeV, dropping out of baryon mass spectra \cite{28}. However, in the $SU(3)$ case, the rotation is distributed among more axes in the flavor space, which causes the individual angular velocity to be smaller and, therefore, baryons with spin 5/2 will be expected to have a narrower width, but a higher mass. For large $N_c$, since mesons $(qq)$ and baryons $(qqq)$ are colorless, baryons are constituted of at least $N_c$. 

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quarks. For specific exoticness $X$, if we assume physical baryon multiplets $(p, q)$ satisfying $I = J$ will maintain $X$ and $J$ for arbitrarily large $N_c$, we can choose

$$ (p, q) = \left( p, \frac{N_c + 3X - p}{2} \right), $$ (1)

with $p$ remains the same as the case of $N_c = 3$, and

$$ J_{\text{max}} = \frac{1}{6} (4p + 2q - N_c). $$ (2)

Such a choice enable us to obtain the 35-plets with spin 5/2 and 3/2 $(4, \frac{N_c - 1}{2})$ in the large $N_c$ limits, as well as the octet $(1, \frac{N_c - 1}{2})$, the decuplet $(3, \frac{N_c + 3}{2})$, the antidecuplet $(0, \frac{N_c + 3}{2})$ and the 27-plets $(2, \frac{N_c + 1}{2})$. And in the large $N_c$ limit, we have

$$ E_{35} - E_{1T0} \rightarrow 0. $$ (3)

Therefore the application of the chiral soliton models to the 35-plet with spin 5/2 is also valid if it is the case for the antidecuplet as argued in Ref. [19].

In this paper, we calculate the masses and the widths of baryons in the 35-plets from chiral soliton models, which are the last ones to be possibly associated with pentaquark states in the quark language. We also discuss $\Delta_{5/2}$ and $\Theta_2$ (or $\Theta^{**}$) with spin 5/2 in details, which are the lightest two members with simplest minimal pentaquark configurations in the 35-plets. Our propose is to give some experimentally testable results about the 35-plets from chiral soliton models. This paper is organized as follows. In Sec. II, we briefly review the $SU(3)$ chiral soliton models. And we give all the masses and the widths of the 35-plet baryons in Sec. III. In Sec. IV, we calculate the widths of $\Delta_{5/2}$ and $\Theta_2$ up to linear order of $m_s$ and $1/N_c$. And we present our conclusion in Sec. V. We list in Appendix the Clebsch-Gordan coefficients involved with the products of the $SU(3)$ irreducible representations 8(1,1) and 35(4,1).

II. THE $SU(3)$ CHIRAL SOLITON MODELS

In the $SU(3)$ chiral soliton models, the classical soliton, which describes baryons, are of the form

$$ U_1(x) = \begin{pmatrix} \exp \left[ i(\hat{\tau} \cdot \tau) F(r) \right] & 0 \\ 0 & 1 \end{pmatrix}, $$ (4)

where $F(r)$ is the spherical-symmetric profile of the soliton, $\tau$ are the three Pauli matrices, and $\hat{\tau}$ is the unit vector in space. And pseudoscalar fields can be written in collective coordinate as

$$ U(x) = \exp \left[ \frac{i\lambda \phi_0(x)}{f_\pi} \right] = A(t)U_1(x)A(t)^{-1}, \ A \in SU(3), $$ (5)

and after quantizing on the collective coordinate $A$, we get the $SU(3)$ chiral symmetry Hamiltonian

$$ H_0 = M_{cl} + \frac{1}{6} \sum_{a=1}^{3} R_{a} R_{a} + \frac{7}{27} \sum_{b=4}^{7} R_{b} R_{b}, $$ (6)

where $R_a$ are the angular momentums conjugate to the angular velocities $\omega^a$, defined by $A^\dagger \partial_0 A = i/\omega^a \lambda^a$, $B$ is the baryon number and $R_8 = N_c B/3$. And the corresponding mass spectra of baryon multiplets are

$$ E_{J}^{(p,q)} = M_{cl} + \frac{1}{6m_c} \left[ p^2 + q^2 + pq + 3(p + q) - \frac{1}{2}(N_c B)^2 \right] + \left( \frac{7}{27} - \frac{1}{27} \right) J(J+1), $$ (7)

where $(p, q)$ denotes an irreducible representation of the $SU(3)$ group, $M_{cl}$, $I_1$ and $I_2$ are given by integrating out the classical soliton, treated model-independently and fixed by experimental data, $M_{cl}$ is the classical soliton mass, $I_1$ and $I_2$ are moments of inertia.

The states of the system will correspond to the baryon waves, and function $\Psi_{\nu\nu'}(B, \bar{B})$ of baryon $B$ in the collective coordinates is of the form

$$ \Psi_{\nu\nu'}(B) = \sqrt{\text{dim}(\mu)} D_{\nu\nu'}^{(\mu)}(A), $$ (8)

where $(\mu)$ denotes an irreducible representation of the $SU(3)$ group; $\nu$ and $\nu'$ denote $(Y, I, I_3)$ and $(1, J, -J_3)$ quantum numbers collectively; $Y$ is the hypercharge of $B$; $I$ and $I_2$ are the isospin and its third component of $B$ respectively; $J_3$ is the third component of spin $J$; $D_{\nu\nu'}^{(\mu)}(A)$ are $SU(3)$ Wigner D-functions. Due to the non-zero strange quark mass, the symmetry breaking Hamiltonian is

$$ H' = \alpha D_{88}^{(8)} + \beta Y + \frac{\gamma}{\sqrt{3}} \sum_{i=1}^{3} D_{8i}^{(8)} J_i, $$ (9)

where the coefficients $\alpha$, $\beta$, $\gamma$ are proportional to the strange quark mass and model dependent; $D_{88}^{(8)}(A)$ is the adjoint representation of the $SU(3)$ group and defined as:

$$ D_{88}^{(8)}(A) = \frac{1}{2} \text{Tr}(A^\dagger \lambda^m A \lambda^n). $$ (10)

By introducing symmetry breaking term we can calculate the mass splitting between baryons of the same baryon multiplets and the physical wave functions. Yabu and Ando [12] proposed a new method to treat the symmetry breaking exactly. However, in this paper, we treat the symmetry breaking term by perturbation theory, and in the case of the octet and the decuplet, it can give experimentally agreeable results [12, 14].

In soliton models, pseudoscalar Yukawa coupling for the process $B \rightarrow B'm$ can be obtained by Goldberger-Treiman relation, which relates the relevant coupling constant to the axial charge [32, 33]. And up to $1/N_c$ order,
III. THE 35-PLET FROM CHIRAL SOLITON MODELS

In the 35-plet, there are $I = 5/2$ and $I = 3/2$ baryons with $Y = 1$, from which we know there are two 35-plets belonging to other baryon multiplets but with the same spin and isospin. For the decuplet and the 35-plet baryons, with $J = 5/2$ and $J = 3/2$ respectively. We suggest the minimal quark configurations of the 35-plets in Fig. 1 and the mass splittings are list in Table I. To fix the parameters model-independently, we choose the second group of data in Refs. [22, 22], which are consistent with the reported narrow $Ξ^-$ baryon resonance with mass of $1.862 \pm 0.003$ GeV and width below the detector resolution of about $0.018$ GeV [34].

| TABLE I: The masses (GeV) of baryons in the 35-plets |
|-----------------------------------------------|
| 35-plet $J = 5/2^+$                      |
| $\Delta$          | 1 | $\frac{1}{2}$ | $\frac{-3}{2}a + \beta - \frac{3}{4}i\gamma$ | 1.96 | $\Delta(1905)$ | $\frac{3}{2}(\frac{3}{2}^+)$ | 1.87 to 1.92 |
| $\Sigma$          | 0 | 1 | $\frac{1}{2}a - \frac{3}{4}i\gamma$ | 2.08 | $\Sigma(1690)$ | $\frac{1}{2}(\frac{1}{2}^+)$ | $\approx 2.07$ |
| $\Xi$             | -1 | $\frac{1}{2}$ | $\frac{3}{2}a - \beta + \frac{3}{4}i\gamma$ | 2.20 | $\Xi(1530)$ | $\frac{1}{2}(\frac{1}{2}^-)$ | $\approx 2.25$ |
| $\Omega$          | -2 | 0 | $\frac{3}{2}a - 2\beta + \frac{3}{4}i\gamma$ | 2.32 | $\Omega(2250)^-$ | $0(\frac{1}{2}^-)$ | $2.252 \pm 0.009$ |
| $\Theta_2$        | 2 | 2 | $\frac{3}{2}a + 2\beta - \frac{3}{4}i\gamma$ | 1.84 | ? | $??(??)$ | ? |
| $\Delta_{5/2}$    | 1 | $\frac{3}{2}$ | $\frac{5}{2}a - \frac{3}{4}i\gamma$ | 1.68 | ? | $??(??)$ | ? |
| $\Sigma_2$        | 0 | 2 | $\frac{3}{2}a + \frac{3}{4}i\gamma$ | 1.86 | ? | $??(??)$ | ? |
| $\Xi_{1/2}$       | -1 | $\frac{1}{2}$ | $\frac{1}{2}a - \beta + \frac{3}{4}i\gamma$ | 2.04 | ? | $??(??)$ | ? |
| $\Omega_1$        | -2 | 1 | $\frac{1}{2}a - 2\beta + \frac{3}{4}i\gamma$ | 2.21 | ? | $??(??)$ | ? |
| $\Phi$            | -3 | 1 | $\frac{3}{2}a - 3\beta + \frac{3}{4}i\gamma$ | 2.30 | ? | $??(??)$ | ? |
| 35-plet $J = 3/2$  |           |               |                                        |
| $\Delta$          | 1 | $\frac{1}{2}$ | $\frac{3}{2}a + \beta + \frac{3}{4}i\gamma$ | 2.45 | ? | $??(??)$ | ? |
| $\Sigma$          | 0 | 1 | $\frac{1}{2}a + \frac{3}{4}i\gamma$ | 2.53 | ? | $??(??)$ | ? |
| $\Xi$             | -1 | $\frac{1}{2}$ | $\frac{3}{2}a - \beta + \frac{3}{4}i\gamma$ | 2.62 | ? | $??(??)$ | ? |
| $\Omega$          | -2 | 0 | $-2\beta + \frac{3}{4}i\gamma$ | 2.70 | ? | $??(??)$ | ? |
| $\Theta_2$        | 2 | 2 | $\frac{3}{2}a + 2\beta - \frac{3}{4}i\gamma$ | 2.37 | ? | $??(??)$ | ? |
| $\Delta_{5/2}$    | 1 | $\frac{3}{2}$ | $\frac{5}{2}a - \frac{3}{4}i\gamma$ | 2.57 | ? | $??(??)$ | ? |
| $\Sigma_2$        | 0 | 2 | $\frac{3}{2}a + \frac{3}{4}i\gamma$ | 2.63 | ? | $??(??)$ | ? |
| $\Xi_{1/2}$       | -1 | $\frac{1}{2}$ | $\frac{1}{2}a - \beta + \frac{3}{4}i\gamma$ | 2.69 | ? | $??(??)$ | ? |
| $\Omega_1$        | -2 | 1 | $\frac{1}{2}a - 2\beta + \frac{3}{4}i\gamma$ | 2.75 | ? | $??(??)$ | ? |
| $\Phi$            | -3 | 1 | $\frac{3}{2}a - 3\beta + \frac{3}{4}i\gamma$ | 2.81 | ? | $??(??)$ | ? |

$^a$already calculated in Ref. [34].

the coupling operator in the space of the collective coordinates $A$ has the form [12, 33]:

$$g_A^{(m)} = G_0D_{m3}^{(8)} - G_1d_{3ab}D_{ma}^{(8)}J_b - \frac{G_2}{\sqrt{3}}D_{m8}^{(8)}J_3,$$ (11)

where $d_{ab}$ is the SU(3) symmetric tensor, $a, b = 4, 5, 6, 7,$ and $J_a = -R_a$. $G_1, G_2$ are dimensionless constants, $1/N_c$ suppressed relative to $G_0$. And the width formula can be obtained by [12, 23]:

$$\Gamma(B \to B') = \frac{3g_{BB'}^{2m}}{4\pi m_B}|p| \left[ (m_{B'}^2 + p^2)^{3/2} - m_{B'}^2 \right],$$ (12)

where $g_{BB'}^{2m}$ can be calculated from $g_A^{(m)}$ [12, 23].

Due to the symmetry breaking Hamiltonian [9], the physical baryon wave functions will mix with those belonging to other baryon multiplets but with the same spin and isospin. For the decuplet and the 35-plet baryons,
by first perturbation, we have

\[ |B^{(10)}_1 \rangle = |B; 10 \rangle + a_{27} |B; 27 \rangle + a_{35} |B; 35 \rangle \]

\[ |B^{(35)}_7 \rangle = |B; 35 \rangle + b_{28} |B; 28 \rangle + b_{64} |B; 64 \rangle + b_{81} |B; 81 \rangle \]

and the coefficients above are given simply by perturbation theory. To calculate the widths of the 35-plet baryons, we first calculate the coupling constant \( \tilde{g}_{AB'B'm}^{(m)} \) from \( g_{AB'} \). From (11), we have

\[
\tilde{g}_{AB'}^{(m)} = G_0 D^{(8)}_{m3} + \frac{\sqrt{2}}{4} G_1 \left(D^{(8)}_{m2} R_{6+7i} + D^{(8)}_{m2-5i} R_{6-7i}\right) - \frac{G_2}{\sqrt{3}} D^{(8)}_{m2} J_3,
\]

where \( D^{(8)}_{m2} = \langle B^{(8)} | D^{(8)} | m \rangle \) and \( R_{a \pm i a} = R_a \pm i R_a \). Trivial algebra will give us

\[
\langle B; 35 | g_A^{(m)} B' ; 10 \rangle = G_{35}^{(10)} \langle B; 35 | D^{(8)}_{m3} B' ; 10 \rangle \]

\[
\langle B; 35 | g_A^{(m)} B' ; 27 \rangle = G_{35}^{(27)} \langle B; 35 | D^{(8)}_{m3} B' ; 27 \rangle \]

\[
\langle B; 35 | g_A^{(m)} B' ; 10 \rangle = G_{35}^{(10)} \langle B; 35 | D^{(8)}_{m3} B' ; 10 \rangle \]

\[
\langle B; 35 | g_A^{(m)} B' ; 27 \rangle = G_{35}^{(27)} \langle B; 35 | D^{(8)}_{m3} B' ; 27 \rangle \]

with

\[
G_{35}^{(10)} = G_0, G_{35}^{(27)} = G_0 + G_1 \]

\[
G_{35}^{(10)} = G_0 - \frac{5}{2} G_1 + \frac{5}{2} G_2, \]

\[
G_{35}^{(27)} = G_0 - \frac{1}{14} G_1 + \frac{15}{14} G_2. \]

Compared with the coupling constant for the decay of antidecuplet baryons \( G_{10}^{(2)} = G_0 - G_1 - 1/2 G_2 \) and the possible narrow width of \( \Theta^+ \), the width of the 35-plet baryons with spin 3/2 will be surprisingly suppressed since in chiral quark-soliton model the ration \( G_1/G_0 \) ranges from 0.4 to 0.6 [33]. Similarly for the decay of 27-plet baryons with spin 1/2 to the octet, the coupling is also small \( G_{27} = G_0 - 2 G_1 + \frac{3}{2} G_2 \) [20]. And in this paper, we will focus only on the 35-plet with spin 5/2. Under the chiral \( SU(3) \) symmetry, we have the following width formula [22]

\[
\Gamma(B \rightarrow B'm) = \frac{G_0^2 |p|}{4 \pi m_B} \left( (m_{B'}^2 + p^2) - m_{B'}^2 \right) \left\{ \sum_{\gamma} \left( \frac{8}{Y_{m} I_{m}} \frac{\mu'_{\gamma}}{Y_{\mu} I_{\mu}} \right) \left( \begin{array}{ccc} 8 & \mu'_{\gamma} & 0 \\ 0 & 1 & \mu'_{\gamma} \end{array} \right) \right\}^2. \]

where we postulate \( B \) with \( (Y, I, I_3; J^P, -J_3) = (Y_\rho, I_\rho, I_3; J^P, -J_3) \), \( B' \) with \( (Y, I, I_3; J^P, -J_3) = (Y_\rho, I_\rho, I_3; J^P, -J_3) \) and \( m \) with \( (Y, I, I_3; J^P, -J_3) = (Y_\mu, I_\mu, I_3; 0, 0) \); and \( G_0^2 = 3.84 G_{35}^2 \). Using this formula, and provided that the width of \( \Theta^+ \), \( \Gamma_{\Theta^+} \leq 25 \text{ MeV} \), we calculate the upper bounds of widths for decay of the 35-plet baryons with spin 5/2 to the 27-plet baryons, listed in Table [21]. From the masses, \( I(J^P) \) and widths, we suggest candidates for all nonexotic members of the 35-plet with spin 5/2 from the available particle listings [27]. For \( \Delta, \Sigma \) and \( \Xi \), it is interesting to see that our calculation, though not as good as those 27-plet nonexotic
may suggest that $\Xi(2250)$, as a member of the 35-plet, is 
minimal pentaquark configurations $|dddd\pi\rangle$ and $|uuuu\pi\rangle$. In Sec. III, we only give the width of 35-plet baryons by the simplification of chiral $SU(3)$ symmetry, and we will calculate the widths of $\Delta_{5/2}$ and $\Theta_2$ up to linear order of $m_q$ and $1/N_c$ below.

From Table II, the physical baryon states are of the form by first-order approximation

\begin{equation}
\langle \Delta \rangle = |\Delta; 10 \rangle + C^{(\Delta)}_{27} |\Delta; 27 \rangle + C^{(\Delta)}_{35} |\Delta; 35 \rangle,
\end{equation}

\begin{equation}
\langle \Delta^* \rangle = |\Delta^*; 27 \rangle + C^{(\Delta^*)}_{10} |\Delta; 10 \rangle + C^{(\Delta^*)}_{35} |\Delta; 35 \rangle + C^{(\Delta^*)}_{64} |\Delta; 64 \rangle,
\end{equation}

| $\Theta^* \rangle = |\Theta^*; 27 \rangle + C^{(\Theta^*)}_{35} |\Theta^*; 35 \rangle + C^{(\Theta^*)}_{64} |\Theta^*; 64 \rangle,\langle \Theta_2 \rangle = |\Theta_2; 27 \rangle + C^{(\Theta_2)}_{35} |\Theta_2; 35 \rangle + C^{(\Theta_2)}_{64} |\Theta_2; 64 \rangle + C^{(\Theta_2)}_{81} |\Theta_2; 81 \rangle,
\end{equation}

\begin{equation}
|\Delta_{5/2} \rangle = |\Delta_{5/2}; 35 \rangle + C^{(\Delta_{5/2})}_{28} |\Delta_{5/2}; 28 \rangle + C^{(\Delta_{5/2})}_{64} |\Delta_{5/2}; 64 \rangle + C^{(\Delta_{5/2})}_{81} |\Delta_{5/2}; 81 \rangle,
\end{equation}

\begin{table}[h]
\centering
\caption{The widths (MeV) of baryons in the 35-plet with spin 5/2}
\begin{tabular}{lllll}
\hline
35-plet baryons & modes & width \ \text{calculation} & total width & PDG data \\
\hline
$\Delta$ & $\Delta\pi$ & 42 & & \\
& $\Delta\eta$ & 63 & 135 & 280 to 400 \\
& $\Sigma^+ K$ & 30 & & \\
\hline
$\Sigma$ & $\Sigma^+ \pi$ & 44 & & \\
& $\Sigma^+ \eta$ & 65 & 161 & $(300 \pm 30)/906/(140 \pm 20)^b$ \\
& $\Xi^+ K$ & 9 & & \\
& $\Delta K$ & 43 & & \\
\hline
$\Xi$ & $\Xi^+ \pi$ & 27 & & \\
& $\Xi^+ \eta$ & 49 & 112 & $(46 \pm 27)/(<30)/(130 \pm 80)^b$ \\
& $\Omega K$ & 1 & & \\
& $\Sigma^* K$ & 35 & & \\
\hline
$\Omega$ & $\Omega\pi$ & 29 & 175 & 55 \pm 18 \\
& $\Xi^* K$ & 146 & & \\
\hline
$\Theta_2$ & $\Delta K$ & 93 & 93 & ? \\
& $\Delta_{5/2}$ & $\Sigma^+ \pi$ & 206 & 206 & ? \\
& & $\Delta K$ & 30 & 30 & \\
\hline
$\Xi_{5/2}$ & $\Xi^* \pi$ & 108 & 176 & ? \\
& & $\Sigma^* K$ & 68 & & \\
\hline
$\Omega_1$ & $\Omega K$ & 180 & 180 & ? \\
\hline
\end{tabular}
\end{table}

\begin{flushleft}
\textsuperscript{b}Data from different Collaborations, and PDG provided no estimations.
\end{flushleft}

candidates, are still consistent with experimental results, but the $\Omega$ candidate is not so ideal. Therefore, we may suggest that $\Xi(2250)$, as a member of the 35-plet, is with the quantum numbers $I(J^P)=\frac{1}{2}(\frac{5}{2}^+)$.

\section{IV. Discussion of $\Delta_{5/2}$ and $\Theta_2$}

From Table II we can see that $\Delta_{5/2}$ are the lightest baryons, and among them, there are $\Delta_{5/2}^-$ and $\Delta_{5/2}^+$, which, in the quark language, are with the simplest minimal pentaquark configurations $|ddddd\pi\rangle$ and $|uuuuu\pi\rangle$ respectively. And in the 35-plets, $\Theta_2$ states with isospin 2, the excitations of $\Theta^+$, include those baryons with min-
with

\[ C_{27}^{(\Delta)} = -\frac{\sqrt{30}}{16} (\alpha + \frac{5}{6}) I_2, \quad C_{35}^{(\Delta)} = -\frac{5\sqrt{14}}{336} (\alpha - \frac{1}{2}) I_2, \quad C_{10}^{(\Delta')} = \frac{\sqrt{30}}{16} (\alpha + \frac{5}{6}) I_2, \]

\[ C_{35}^{(\Delta')} = -\frac{105}{70} (\alpha + \frac{5}{6} \gamma) I_2, \quad C_{35}^{(\Delta')} = -\frac{5\sqrt{3}}{196} (\alpha + \frac{5}{6} \gamma) I_2, \quad C_{64}^{(\Delta')} = -\frac{5\sqrt{3}}{196} (\alpha + \frac{5}{6} \gamma) I_2, \]

\[ C_{81}^{(\Delta_{5/2})} = -\frac{7\sqrt{15}}{960} (\alpha - \frac{1}{2} \gamma) I_2, \quad C_{81}^{(\Delta_{5/2})} = -\frac{7\sqrt{15}}{960} (\alpha - \frac{1}{2} \gamma) I_2. \]

Substituting the parameters into these coefficients, we have

\[ C_{27} = 0.44, \quad C_{35} = 0.09, \quad C_{10}^{(\Delta')} = -0.44, \quad C_{35}^{(\Delta')} = 0.19, \quad C_{64}^{(\Delta')} = 0.10, \quad C_{64}^{(\Delta')} = 0.08, \]

\[ C_{64}^{(\Theta^2)} = 0.16, \quad C_{64}^{(\Theta^2)} = 0.08, \quad C_{64}^{(\Theta^2)} = 0.22, \quad C_{81}^{(\Delta_{5/2})} = 0.05, \quad C_{81}^{(\Delta_{5/2})} = 0.10, \quad C_{81}^{(\Delta_{5/2})} = 0.22, \quad C_{81}^{(\Delta_{5/2})} = 0.04. \]

By the general width formula, for the decay of \( \Delta_{5/2} \) and \( \Theta_2 \) to the octet baryons, we have

\[ \Gamma(\Theta_2 \to \Delta K) = g_0 \frac{G_0^2}{14\pi m_{\Theta_2}} |p| \left[ (m_\Delta^2 + p^2)^{\frac{1}{2}} - m_\Delta \right] \left( 1 \frac{\sqrt{30}}{C_{27}} \right) < 65 \text{ MeV}, \]

\[ \Gamma(\Delta_{5/2} \to \Delta \pi) = g_0 \frac{G_0^2}{14\pi m_{\Delta_{5/2}}} |p| \left[ (m_\Delta^2 + p^2)^{\frac{1}{2}} - m_\Delta \right] \left( 1 \frac{\sqrt{30}}{C_{27}} + \frac{\sqrt{14}}{10} C_{35} \right) < 380 \text{ MeV}, \]

and, also, to the 27-plet baryon \( \Theta^* \)

\[ \Gamma(\Theta_2 \to \Theta^* \pi) = g_0 \frac{3(G_0 + G_1)^2}{70\pi m_{\Theta_2}} |p| \left[ (m_\Delta^2 + p^2)^{\frac{1}{2}} - m_\Delta \right] \left( 1 + \frac{\sqrt{10}}{G_0 + G_1} C_{64}^{(\Theta^*)} + \frac{\sqrt{35}}{4} \frac{G_0}{G_0 + G_1} C_{64}^{(\Theta^*)} \right) < 35 \text{ MeV}. \]

and other processes are prohibited by the conservations of energy and momentum and the numeric values are estimated provided that \( \Gamma_{\Theta^+} < 25 \text{ MeV} \).

V. SUMMARY AND CONCLUSIONS

The baryon 35-plets with spin 5/2 and 3/2 are the last two \( SU(3) \) multiples with exoticness \( X = 1 \), which may be associated with so-called pentaquark states. And we give all the masses of the 35-plet baryons (Table II), and to estimate their widths, we also calculate the coupling constants by Goldberger-Treiman relation. We find that 35-plet with spin 3/2 have a even more narrow coupling constant for the decay of those baryons to the decuplet baryons than the antidecuplet, while that for the process involved with the 27-plet baryons with 3/2 are relatively large. In contrast, the coupling constants for the 35-plet with spin 5/2 are larger than that of the antidecuplet, which enable those baryons to possess a much broader width than that of the antidecuplet baryons, as listed in Table II.

To give experimentally testable results further, we calculate the widths of \( \Delta_{5/2} \) and \( \Theta_2 \) up to linear order of \( m_s \) and \( 1/N_c \). \( \Delta_{5/2} \), in the quark language, may be the simplest pentaquark states of pentaquark configuration only involving \( u \) and \( d \) quarks and there are \( \Delta_{5/2}^{++}(uuu\bar{u}) \) and \( \Delta_{5/2}^{--}(ddd\bar{d}) \) in these isospin multiplet. And due to the conservation of energy and momentum, the decay of \( \Delta_{5/2} \) to the 27-plet baryons are prohibited. Therefore, those baryons can only be revealed by the decay processes involving the decuplet baryons

\[ \Delta_{5/2}^{++} \to \Delta^{++}\pi^+, \]

\[ \Delta_{5/2}^{--} \to \Delta^-\pi^-. \]

According to the calculation in Sec. IV, we estimate \( \Gamma_{\Delta_{5/2}} < 380 \text{ MeV} \) if we choose \( \Gamma_{\Theta^+} < 25 \text{ MeV} \) and assume that the width are dominated by two-body decay. The \( \Theta_2 \) states, including \( \Theta_2^{++}(uuu\bar{s}) \), \( \Theta_2^{'+}(uuud\bar{s}) \),
\(\Theta^+_2(uudd\bar{s}), \Theta^0_2(udds\bar{s}), \text{ and } \Theta^-_2(ddds\bar{s})\), can decay to the decuplet baryons and the 27-plet baryons with spin 3/2, i.e.,

\[
\begin{align*}
\Theta_2 &\rightarrow \Delta K, \\
\Theta_2 &\rightarrow \Theta^*\pi.
\end{align*}
\]

and the total width \(\Gamma_{\Theta_2} < 100\) MeV on the assumption of \(\Gamma_{\Theta^+} < 25\) MeV and dominance of two-body decay.

In summary, as argued by Diakonov and Petrov [19], chiral soliton models are valid in the predictions about the exotic baryon multiplets when the exoticness is small comparable with \(N_c\). And among the baryon multiplets with exoticness=1, such as the antidecuplet, 35-plets with spin 5/2 and 3/2 are the last (most weighted) two baryon multiplets from the chiral soliton models which may be described by pentaquark states in quark language. And in this paper we investigate the 35-plet baryons and suggest all nonexotic members with spin 5/2 from the available particle listings. We focus on the baryons with spin 5/2, especially \(\Delta_5^{5/2}\) and \(\Theta_2\), which are of simplest pentaquark configurations and find that \(\Delta_5^{5/2}\) have a width much less than the prediction from the \(SU(2)\) Skyrme Model, which is physically testable. These two baryons both have a typical width of strong decay, and the search of them are also of great significance to test the validity of application of chiral soliton models to these so-called exotic baryon multiplets in the eyes of the quark model.

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**APPENDIX:** The Clebsch-Gordan Coefficients for the product of \(35(4,2) \otimes 8(1,1)\)

In this paper, we use frequently the Clebsch-Gordan Coefficients for the product of the \(SU(3)\) irreducible representations \(35(4,2) \otimes 8(1,1)\), which decomposes as

\[
35\ (4,2) \otimes 8(1,1) = 10(3,0) \oplus 28(6,0) \oplus 27(2,2) \oplus 35^{(1)}(4,1) \oplus 35^{(2)}(4,1) \oplus 64(3,3) \oplus 81(5,2).
\]

To be convenient, we define

\[
\mu^{(\lambda)}_{(\nu)} = \sum_{\nu_1, \nu_2} \left( \begin{array}{ccc} \mu_1 & \mu_2 & \mu \\ \nu_1 & \nu_2 & \nu \end{array} \right) \mu_{1(\nu_1)} \mu_{2(\nu_2)},
\]

where \(\mu^{\lambda}_{(\nu)}\) denote the eigenstates of the representation \(\mu\) contained in the direct sum of \(\mu_1\) and \(\mu_2\), whose eigenstates are \(\mu_{1(\nu_1)}\) and \(\mu_{2(\nu_2)}\) respectively, \(\lambda\) is used to distinguish identical but independent representations which are all contained in \(\mu_1 \otimes \mu_2\), \(\nu, \nu_1\) and \(\nu_2\) denote quantum number \((Y I I_3)\) collectively, and \(\left( \begin{array}{ccc} \mu_1 & \mu_2 & \mu \\ \nu_1 & \nu_2 & \nu \end{array} \right)\) are the \(SU(3)\) Clebsch-Gordan coefficients. We define

\[
I_{\pm} = F_1 \pm iF_2,
\]

\[
K_{\pm} = F_4 \pm iF_5,
\]

\[
L_{\pm} = F_6 \pm iF_7,
\]

where \(F_a\) are the generators of the \(SU(3)\) group. Following the conventions used in Ref. [37], we choose all the coefficients of any states given by the action of \(I_{\pm}\) and \(K_{\pm}\) on any eigenstates of \(F_1\) and \(F_8\) are nonnegative and give the follow decomposition.
\[81_{\frac{3}{2}} = 35_{222}8_{1 \frac{3}{4}},\]

\[81_{222} = \frac{\sqrt{30}}{30}35_{222}8_{010} + \frac{3\sqrt{10}}{20}35_{222}8_{000} - \frac{\sqrt{15}}{30}35_{221}8_{011} - \frac{\sqrt{15}}{60}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}} + \frac{\sqrt{3}}{60}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}} + \frac{3\sqrt{2}}{5}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}},\]

\[81_{\frac{3}{4}} = \frac{\sqrt{35}}{20}35_{222}8_{-1 \frac{3}{4}} + \frac{3\sqrt{70}}{280}35_{1 \frac{3}{4}}8_{010} + \frac{\sqrt{210}}{40}35_{1 \frac{3}{4}}8_{000} - \frac{3\sqrt{7}}{140}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{42}}{10}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{35}}{10}35_{022}8_{1 \frac{3}{4}},\]

\[64_{222} = \frac{\sqrt{30}}{15}35_{222}8_{010} - \frac{\sqrt{10}}{5}35_{222}8_{000} - \frac{\sqrt{15}}{15}35_{221}8_{011} + \frac{2\sqrt{15}}{15}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}} - \frac{3\sqrt{2}}{15}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}} + \frac{\sqrt{7}}{5}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}},\]

\[64_{211} = \frac{\sqrt{105}}{35}35_{222}8_{011} - \frac{\sqrt{210}}{70}35_{221}8_{010} + \frac{\sqrt{210}}{70}35_{222}8_{010} + \frac{3\sqrt{14}}{14}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}} - \frac{\sqrt{42}}{14}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}},\]

\[64_{1 \frac{3}{2}} = \frac{2\sqrt{15}}{15}35_{222}8_{-1 \frac{1}{2}} + \frac{3\sqrt{30}}{35}35_{1 \frac{3}{4}}8_{010} - \frac{\sqrt{10}}{5}35_{1 \frac{3}{4}}8_{000} - \frac{2\sqrt{3}}{15}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{7}}{5}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{15}}{15}35_{022}8_{1 \frac{3}{4}},\]

\[64_{1 \frac{1}{2}} = \frac{2\sqrt{7}}{35}35_{222}8_{-1 \frac{1}{2}} + \frac{\sqrt{7}}{35}35_{221}8_{-1 \frac{1}{2}} + \frac{2\sqrt{7}}{35}35_{1 \frac{3}{4}}8_{011} - \frac{2\sqrt{70}}{175}35_{1 \frac{3}{4}}8_{010} + \frac{\sqrt{70}}{175}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{3}}{25}35_{1 \frac{3}{4}}8_{011} + \frac{3\sqrt{7}}{35}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{7}}{7}35_{011}8_{1 \frac{3}{4}},\]

\[28_{233} = \frac{\sqrt{3}}{2}35_{222}8_{011} - \frac{\sqrt{2}}{2}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}},\]

\[28_{1 \frac{3}{4}} = \frac{\sqrt{3}}{6}35_{222}8_{-1 \frac{3}{4}} - \frac{\sqrt{6}}{12}35_{1 \frac{3}{4}}8_{010} - \frac{\sqrt{3}}{4}35_{1 \frac{3}{4}}8_{000} + \frac{\sqrt{15}}{30}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{10}}{5}35_{1 \frac{3}{4}}8_{011} - \frac{\sqrt{3}}{3}35_{022}8_{1 \frac{3}{4}},\]

\[35_{222} = \frac{2}{3}35_{222}8_{010} + \frac{2\sqrt{3}}{9}35_{222}8_{000} - \frac{\sqrt{2}}{3}35_{221}8_{011} - \frac{\sqrt{15}}{9}35_{1 \frac{3}{4}}8_{1 \frac{3}{4}},\]

\[35_{1 \frac{3}{2}} = \frac{2}{3}35_{1 \frac{3}{4}}8_{010} + \frac{2\sqrt{3}}{9}35_{1 \frac{3}{4}}8_{000} - \frac{2\sqrt{10}}{15}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{15}}{45}35_{1 \frac{3}{4}}8_{011} - \frac{\sqrt{2}}{3}35_{022}8_{1 \frac{3}{4}},\]

\[35_{1 \frac{1}{2}} = \frac{\sqrt{15}}{9}35_{222}8_{-1 \frac{1}{2}} + \frac{\sqrt{15}}{18}35_{221}8_{-1 \frac{1}{2}} - \frac{\sqrt{15}}{45}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{6}}{45}35_{1 \frac{3}{4}}8_{011} - \frac{\sqrt{6}}{90}35_{1 \frac{3}{4}}8_{011} + \frac{31}{60}35_{1 \frac{3}{4}}8_{010} + \frac{\sqrt{3}}{12}35_{1 \frac{3}{4}}8_{010} - \frac{31\sqrt{6}}{180}35_{1 \frac{3}{4}}8_{011} + \frac{\sqrt{15}}{90}35_{022}8_{1 \frac{3}{4}} - \frac{\sqrt{15}}{180}35_{021}8_{1 \frac{3}{4}} + \frac{\sqrt{3}}{36}35_{011}8_{1 \frac{3}{4}},\]

\[35_{022} = \frac{\sqrt{2}}{3}35_{1 \frac{3}{4}}8_{-1 \frac{3}{4}} - \frac{\sqrt{10}}{15}35_{1 \frac{3}{4}}8_{-1 \frac{3}{4}} + \frac{\sqrt{15}}{90}35_{1 \frac{3}{4}}8_{-1 \frac{3}{4}} + \frac{1}{2}35_{022}8_{010} + \frac{\sqrt{3}}{18}35_{022}8_{000} - \frac{\sqrt{2}}{4}35_{021}8_{011} + \frac{\sqrt{2}}{12}35_{011}8_{011} - \frac{\sqrt{3}}{3}35_{-1 \frac{3}{4}}8_{1 \frac{3}{4}},\]
\[
35_{111} = \frac{5\sqrt{15}}{36} \cdot 35_{4\frac{1}{2}} \cdot 35_{8 - \frac{1}{2} + \frac{1}{2}} - \frac{5\sqrt{15}}{36} \cdot 35_{4\frac{1}{2}} \cdot 35_{8 - \frac{1}{2} + \frac{1}{2}} - \frac{\sqrt{7}}{18} \cdot 35_{022} \cdot 35_{011} + \frac{1}{12} \cdot 35_{021} \cdot 35_{8010} - \frac{\sqrt{3}}{36} \cdot 35_{020} \cdot 35_{011} + \frac{13}{36} \cdot 35_{011} \cdot 35_{8010}
\]

\[
- \frac{\sqrt{3}}{18} \cdot 35_{0011} \cdot 35_{1000} - \frac{13}{36} \cdot 35_{010} \cdot 35_{011} + \frac{\sqrt{7}}{18} \cdot 35_{-1\frac{1}{2}} \cdot 8 \cdot \frac{1}{2} - \frac{1}{18} \cdot 35_{-1\frac{1}{2}} \cdot 8 \cdot \frac{1}{2} - \frac{5}{9} \cdot 35_{-1\frac{1}{2}} \cdot 8 \cdot \frac{1}{2}
\]

\[
35_{1\frac{1}{2}} = \frac{\sqrt{3}}{3} \cdot 35_{022} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} + \frac{\sqrt{3}}{18} \cdot 35_{0211} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} + \frac{1}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 35_{8010} - \frac{\sqrt{3}}{9} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8000 - \frac{\sqrt{3}}{9} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011
\]

\[
+ \frac{\sqrt{6}}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011 - \frac{\sqrt{3}}{3} \cdot 35_{211} \cdot 35_{1\frac{1}{2}}
\]

\[
35_{1\frac{1}{2}} = \frac{5}{9} \cdot 35_{011} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} + \frac{5\sqrt{2}}{18} \cdot 35_{010} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} - \frac{\sqrt{6}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011 - \frac{1}{9} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8010 - \frac{\sqrt{2}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011
\]

\[
+ \frac{7}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8010 - \frac{7\sqrt{6}}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8000 + \frac{7\sqrt{6}}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011 + \frac{1}{6} \cdot 35_{-211} \cdot 8 \cdot \frac{1}{2} - \frac{\sqrt{7}}{12} \cdot 35_{-210} \cdot 8 \cdot \frac{1}{2} - \frac{5\sqrt{2}}{18} \cdot 35_{-200} \cdot 8 \cdot \frac{1}{2}
\]

\[
35_{1\frac{1}{2}} = \frac{\sqrt{3}}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-211} \cdot 8010 - \frac{5\sqrt{3}}{18} \cdot 35_{-210} \cdot 8000 - \frac{1}{6} \cdot 35_{-210} \cdot 8011
\]

\[
+ \frac{\sqrt{3}}{18} \cdot 35_{-200} \cdot 8011 - \frac{\sqrt{3}}{9} \cdot 35_{-3\frac{1}{2}} \cdot 8 \cdot \frac{1}{2}
\]

\[
35_{1\frac{1}{2}} = \frac{5\sqrt{3}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} - \frac{5\sqrt{3}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} - \frac{\sqrt{6}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011 - \frac{1}{9} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8010 - \frac{\sqrt{2}}{18} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011
\]

\[
+ \frac{7}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8010 - \frac{7\sqrt{6}}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8000 + \frac{7\sqrt{6}}{36} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8011 + \frac{1}{6} \cdot 35_{-211} \cdot 8 \cdot \frac{1}{2} - \frac{\sqrt{7}}{12} \cdot 35_{-210} \cdot 8 \cdot \frac{1}{2} - \frac{5\sqrt{2}}{18} \cdot 35_{-200} \cdot 8 \cdot \frac{1}{2}
\]

\[
35_{1\frac{1}{2}} = \frac{\sqrt{3}}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-211} \cdot 8010 - \frac{5\sqrt{3}}{18} \cdot 35_{-210} \cdot 8000 - \frac{1}{6} \cdot 35_{-210} \cdot 8011
\]

\[
+ \frac{\sqrt{3}}{18} \cdot 35_{-200} \cdot 8011 - \frac{\sqrt{3}}{9} \cdot 35_{-3\frac{1}{2}} \cdot 8 \cdot \frac{1}{2}
\]

\[
35_{1\frac{1}{2}} = \frac{\sqrt{3}}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{3} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-1\frac{1}{2} - \frac{1}{2}} \cdot 8 \cdot \frac{1}{2} + \frac{1}{6} \cdot 35_{-211} \cdot 8010 - \frac{5\sqrt{3}}{18} \cdot 35_{-210} \cdot 8000 - \frac{1}{6} \cdot 35_{-210} \cdot 8011
\]

\[
+ \frac{\sqrt{3}}{18} \cdot 35_{-200} \cdot 8011 - \frac{\sqrt{3}}{9} \cdot 35_{-3\frac{1}{2}} \cdot 8 \cdot \frac{1}{2}
\]
And others can be obtained by the action of $I_{\pm}$ and $K_{\pm}$ on given decomposition and the action rules on $\mu^{(\lambda)}_{(\nu)}$ are as follows

$$O\mu^{(\lambda)}_{(\nu)} = \sum_{\nu_1, \nu_2} \left( \frac{\mu_1}{\nu_1} \frac{\mu_2}{\nu_2} \mu \right) \left[ (O\mu_{(\nu_1)}) \mu_{2(\nu_2)} + \mu_{1(\nu_1)} (O\mu_{2(\nu_2)}) \right],$$

where $O$ denotes any one operator in (28)-(30).

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