NEGATIVE PARITY BARYON RESONANCES AND BROKEN $SU_6 \times SU_6$ SYMMETRY

D. V. Volkov *)

CERN - Geneva

*) On leave from the Physical-Technical Institute, Kharkov, U.S.S.R.

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In this letter we consider three different possible assignments of representations of the $SU_6 \times SU_6$ group to the negative parity baryon resonances, and the consequences which follow for the interaction of these resonances with $(56,1)$ baryonic and $(6,\overline{6})$ mesonic $SU_6 \times SU_6$ multiplets.

The considered representations are $(1,70)$, $(15,6)$ and $(21,6)$. Their $SU_3 \times SU_2$ content is as follows :

$$
\begin{aligned}
(1,70) &\sim 8_{\frac{3}{2}},\ 1_{\frac{1}{2}},\ 8_{\frac{1}{2}},\ 10_{\frac{1}{2}} \\
(21,6) &\sim 8_{\frac{3}{2}},\ 10_{\frac{3}{2}},\ 1_{\frac{1}{2}},\ 8_{\frac{1}{2}},\ 8_{\frac{1}{2}},\ 10_{\frac{1}{2}} \\
(15,6) &\sim 1_{\frac{3}{2}},\ 8_{\frac{3}{2}},\ 1_{\frac{1}{2}},\ 8_{\frac{1}{2}},\ 8_{\frac{1}{2}},\ 10_{\frac{1}{2}} .
\end{aligned}
\tag{1}
$$

For labelling $SU_3 \times SU_2$ multiplets we use $(SU_3)_J$ notation, where J is spin value.

To avoid the complication due to mixing of states with the same values of hypercharge and isospin, we choose to consider only non-mixing states of the $8_{\frac{3}{2}}$ and $10_{\frac{1}{2}}$ multiplets. The possible candidates for the particles of these multiplets are $N^*_{\frac{1}{2}}(1512)$, $Y^*_0(1520)$, $Y^*_1(1660)$, $\Xi^*(1810)$ [or the recently discovered $\Xi^*(1705)$] for the $8_{\frac{3}{2}}$ octet, and $N^*_{\frac{3}{2}}$ (S wave πN resonance) for the $10_{\frac{1}{2}}$ decuplet. In both Ξ^* cases no information about spin and parity is now available so the assignment is only a tentative one.

In broken $SU_6 \times SU_6$ symmetry (moving $(SU_6)_W$ subgroup of $SU_6 \times SU_6$ [1]) the vertices for each of the transitions $(1,70) \to (56,1),(6,\overline{6})$ and $(15,6) \to (56,1),(6,\overline{6})$ contain only one amplitude. These are given by the following expressions :

$$
\begin{aligned}
A(1,70) = {} & \sqrt{2}\left[(10_{\frac{3}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + (10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_2\right] + \\
& + \frac{1}{3}\left[(8_{\frac{1}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + 3(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_D - (8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_F\right] \\
A(15,6) = {} & -\frac{1}{\sqrt{2}}\left[(10_{\frac{3}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + (10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_2\right] + \\
& + \frac{1}{6}\left[(8_{\frac{1}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + 2(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_F\right]
\end{aligned}
\tag{2}
$$

where

$$(10_{\frac{3}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) = (10)^{abc}(8)^{c'}_{c}(10)_{abc'} \times (\tfrac{3}{2})^{\alpha\beta\gamma}\, n^{\alpha'}_{\alpha}\, n^{\beta'}_{\beta}\, (\tfrac{1}{2})_{\alpha'}\, \epsilon_{\beta'\gamma}$$

$$(10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_1 = (10)^{abc}(8)^{c'}_{c}(8)^{n}_{a}\epsilon_{nbc'} \times (\tfrac{3}{2})^{\alpha\beta\gamma}(\tfrac{3}{2})_{\alpha+\beta+\gamma}$$

$$(10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_2 = (10)^{abc}(8)^{c'}_{c}(8)^{n}_{a}\epsilon_{nbc'} \times (\tfrac{3}{2})^{\alpha\beta\gamma}(\tfrac{3}{2})_{\alpha'\beta'\gamma}\, n^{\alpha'}_{\alpha}\, n^{\beta'}_{\beta}$$

$$(8_{\frac{1}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) = (8)^{a}_{m}\epsilon^{mbc}(8)^{c'}_{c}(10)_{abc'} \times (\tfrac{1}{2})^{\alpha}(\tfrac{1}{2})_{\alpha}$$

$$2(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_D = \left[(8)^{a}_{c}(8)^{b}_{a}(8)^{c}_{b} + (8)^{a}_{c}(8)^{c}_{b}(8)^{b}_{a}\right](\tfrac{1}{2})^{\alpha}\epsilon^{\beta\gamma}\, n^{\alpha'}_{\alpha}\, n^{\gamma'}_{\gamma}\, (\tfrac{3}{2})_{\alpha'\gamma'\beta}$$

$$2(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_F = \left[(8)^{a}_{c}(8)^{b}_{a}(8)^{c}_{b} - (8)^{a}_{c}(8)^{c}_{b}(8)^{b}_{c}\right](\tfrac{1}{2})^{\alpha}\epsilon^{\beta\gamma}\, n^{\alpha'}_{\alpha}\, n^{\gamma'}_{\gamma}\, (\tfrac{3}{2})_{\alpha'\gamma'\beta} \qquad (3)$$

$(10)^{abc}$, $(8)^{b}_{a}$ and $(\frac{3}{2})^{\alpha\beta\gamma}$, $(\frac{1}{2})^{\alpha}$,... are the wave functions of the SU_3 and spin multiplets normalized to one for every physical state. The order of writing down of SU_3 and SU_2 labels is the same on the right and left-hand sides. n^{α}_{β} in (3) denotes $(\vec{\epsilon}\,\vec{n})^{\alpha}_{\beta}$.

The matrix element for the transition $(21,6) \rightarrow (56,1),(6,\bar{6})$ contains two independent amplitudes

$$A(21,6)_1 = \sqrt{2}\,(10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_1 + (8_{\frac{1}{2}},8_0 \leftarrow 10_{\frac{1}{2}})$$

and (4)

$$A(21,6)_2 = -\frac{1}{\sqrt{2}}\left[(10_{\frac{3}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + (10_{\frac{3}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_2\right] + $$

$$+ \frac{1}{6}\left[5(8_{\frac{1}{2}},8_0 \leftarrow 10_{\frac{1}{2}}) + 6(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_D + 4(8_{\frac{1}{2}},8_0 \leftarrow 8_{\frac{3}{2}})_F\right].$$

The branching ratios for different decay modes can be easily evaluated from (2) and (4). We list below those of them which can be compared with the existing experimental data.

Decaying particle and branching ratio / Representation		$N^*_{\frac{1}{2}}(1512)$ $N^*\pi/N\pi$	$Y^*_1(1520)$ $N\bar{K}/\Sigma\pi$	$Y^*_1(1660)$ $\Sigma\pi:\Lambda\pi:N\bar{K}:Y^*\pi$	$\Xi^*(1800)$ $\Sigma\bar{K}:\Lambda\bar{K}:\Xi\pi:\Xi^*\pi$
(1.70)	uncorrected	20	0	1 : $\frac{3}{2}$: 4:5	1: 1: 4 :5
	corrected	0.02	0	1 : 5 : 7:0.005	1: 9: 48 :0.2
(21.6)	uncorrected	--	1.5	--	--
	corrected	--	1.65	--	--
(15.6)	uncorrected	20	--	4 : 0 : 1:5	1: 1: 1 :5
	corrected	0.35	--	2.6: 0 : 1:0.1	1: 3: 3.6:0.6
Experiment [2]		0.25	0.55	32 : 6 :16: ?	$<$10:45:$<$10 : ?

In the lower lines, the branching ratios are corrected for the phase space and the q^2 dependence of the decay amplitudes $[A(1,70) \sim q^4;\ A(15,6), A(21,6) \sim q^2]$.

From the Table it follows that the best agreement with the experimental data is for the (15,6) multiplet. An attractive feature of this multiplet is also that it contains an SU_3 singlet with $\frac{3}{2}$ spin. For a pure singlet, the $N\bar{K}/\Sigma\pi$ ratio is equal to 2/3 which is near to the experimental value.

The branching ratio for $\Xi^-(1810)$ decay in all considered variants differs significantly from the experimental value. Better results may be expected for the $\Xi^*(1705)$ resonance which seems to be strongly coupled to both $\Lambda\bar{K}$ and $\Xi\pi$ channels [3].

As the parities of $\frac{3}{2}^-$ resonances are not finally determined it is worth while to note that the same results for the uncorrected branching ratios can be obtained for the positive parity (70,1), (6,15) and (6,21) multiplets. The corrected branching ratios are sensitive to parity of multiplets due to change in the q dependence of the matrix elements.

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After this work was completed, the author learned of similar work by Harari et al. [4] who considered the possible (70,1) assignment to positive parity baryon resonances.

R E F E R E N C E S

1) R.F. Dashen and M. Gell-Mann, Phys. Letters 17, 142, 145 (1965).

2) A.H. Rosenfeld, A. Barbaro-Galtieri, W.H. Barkas, P.L. Bastien, J. Kirtz and M. Roos, Revs. Modern Phys. 36, 977 (1964).

3) G.A. Smith and J.S. Lindsey (preprint UCRL-16162).

4) H. Harari, D. Horn, M. Kugler, H.J. Lipkin and S. Meshkov (preprint).