The mass structure of SU(3) baryon multiplets

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Introduction The SU(3) symmetry of strong interactions was the first and probably the most successful idea for the systematization of elementary particles. In this classication scheme, strongly interacting particles with the same quantum numbers of spin and parity are placed into various irreducible representations of the SU(3) flavor group. The examples of well established SU(3) multiplets are of $J^P=\frac{1}{2}^-$ octet and $J^P=\frac{1}{2}^-$ decuplet[1]. The mass splittings inside a given SU(3) multiplet arising from approximate nature of the SU(3) symmetry are described by the Gell-Mann-Okubo (GMO) mass formula[2]. This formula yields well known equal spacing rule for the decuplet and antidecuplet.

In the present study we show the mass differences among octet, decuplet and antidecuplet baryons to be close integral multiples of 29.318 MeV, the mass difference between a neutral pion and a muon, in line with the general tendency of elementary particle mass differences to be close integral/half integral multiple of this mass unit[3].

Baryon Octet The database for the present study is the 2008 Particle Data Group listings. The column 2 of Table I shows mass differences (Δm) between the octet baryons. The small mass differences within the members of an isospin multiplet are known to arise due to the electromagnetic interaction. However, the masses of the members of different isospin multiplets differ considerably. Column 4 shows the integral multiples of 29.318 MeV that are close to the observed mass difference between successive members of the octet. The integers being shown in Column 3. The deviations of the observed value from the closest

TABLE I: The observed baryon octet mass intervals as integral multiple of 29.318 MeV

Particles	Δm (MeV)	N	$N\times$29.318 (MeV)	Obsd - Expd (MeV)
Λ^0 - n	176.118	6	175.908	0.21
Σ^+ - Λ^0	73.687	3	87.954	14.267
		$\frac{5}{2}$	73.295	0.392
Ξ^0 - Σ^-	117.381	4	117.272	0.109
Ξ^- - p	383.038	13	381.134	1.904

integral multiple of 29.318 MeV are given in Column 5. It is observed that 176.118 MeV, the mass difference between Λ^0 and n differs from the nearest predicted value of 175.908 MeV by only 0.21 MeV. Same is true of the mass difference i.e. 117.381 MeV between the particles Ξ^0 and Σ^- which differs from the predicted value of 117.272 MeV by only 0.109 MeV. However, observed mass interval of Σ^+ and Λ^0 differs from the predicted value by about 14.264 MeV. Interestingly, this large value turns out to be half integral multiple of the mass difference between a π^0 and a μ^-. As can be clearly seen from the row 3 of Table I, the observed mass difference between Σ^+ and Λ^0 i.e. 73.69 differs from the half integral ($\frac{5}{2}$) multiple of pion and muon mass difference by only 0.39 MeV. The mass difference of 383.038 MeV, between the heaviest member Ξ^- and the lightest baryon p is close integral multiple of 29.318 MeV, differing from the predicted value by only 1.904 MeV.

Baryon Decuplet The analysis for the baryon decuplet with $J^P=\frac{3}{2}^-$ is detailed in Table II. We consider the average masses of each isospin multiplet Δ, Σ^*, Ξ^* and Ω^-. The first three mass differences in the Table II are those between the successive members of the decuplet. Although the mass spacing among the successive decuplet members deviate from the closest integral (5) multiples of 29.318

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TABLE II: The observed baryon decuplet mass intervals as integral multiple of 29.318 MeV

Particles	Δm (MeV)	N	$N\times$29.318 (MeV)	Obsd - Expd (MeV)
Σ^* - Δ	152.56	5	146.59	5.97
Ξ^* - Σ^*	148.84	5	146.59	2.25
Ω^- - Ξ^*	139.05	5	146.59	7.54
	146.816	5	146.59	0.226
Ω^- - Δ	440.45	15	439.77	0.68

TABLE III: The observed antidecuplet baryon mass intervals as integral multiple of 29.318 MeV

Particles	Δm (MeV)	N	$N\times$29.318 (MeV)	Obsd - Expd (MeV)
N^* - Θ^+	145.8	5	146.59	0.79
$\Xi^-_{3/2}$ - N^*	177	6	175.908	1.092
$\Xi^-_{3/2}$ - Θ^+	322.8	11	322.498	0.302

MeV by 5.97, 2.25 and 7.54 MeV respectively, the average mass difference among successive members i.e. 146.816 MeV is very close to 146.59 MeV, a value obtained on integral (5) multiplication of 29.318 MeV. The difference between the observed and predicted values being 0.226 MeV only. The observed mass interval of Δ and the Ω^- is 440.45 MeV which differs from the predicted value of 439.77 MeV, obtained on integral (15) multiplication of the mass difference between a neutral pion and a muon by only 0.68 MeV.

Baryon Antideuplet The Θ^+ lightest member of the antidecuplet, first predicted in the chiral soliton model[4] is an isosinglet state[5] with a mass of 1539.2 ± 1.6 MeV. The mass of $\Xi^-_{3/2}$, member of the Ξ multiplet of the antidecuplet is measured to be 1862 ± 2 MeV[6]. Quite recently the evidence for the existence of $N^*(1685)$ with a mass of 1685±5±7 MeV, the non-strange member of the antidecuplet has been claimed[7]. The fourth member of the antidecuplet Σ is yet to be detected.

From Table III it is observed that the mass difference between $N^*(1685)$ and Θ^+ i.e. 145.8 MeV differs from the nearest predicted value of 146.59 MeV by only 0.79 MeV. Same is true of the mass difference i.e. 177 MeV between the particles $\Xi^-_{3/2}$ and $N^*(1685)$ which differs from the predicted value of 175.908 MeV by only 1.092 MeV. Further, 322.8 MeV, the observed mass difference between $\Xi^-_{3/2}$ and Θ^+ differs from the integral (11) multiple 29.318 MeV by only 0.302 MeV.

Discussion The equal spacing rule for the SU(3) decuplet and antidecuplet predicts masses of successive isospin multiplets to be equidistant. However, this rule is strictly obeyed neither for the decuplet nor for the antidecuplet since the mass separations are not exactly same. On the other hand we have shown that the mass splittings within the octet, decuplet and antidecuplet members are exact integral multiple of the mass difference between a neutral pion and muon, an effect that appears to be valid for the whole elementary particle mass spectrum[3]. The fact that the mass differences of the leptons, mesons, baryons and pentaquark baryons are integral multiples of 29.318 MeV clearly indicates that the quark structure of the elementary particles seems to be irrelevant as for as this effect is concerned. Further, our study reveals that the strength of the SU(3) breaking, understood to give members of the same multiplet different masses can take only certain values, discrete as integral multiple of the mass difference between a neutral pion (hadron) and a muon (lepton).

References

[1] M. Gell-Mann and Y. Ne'eman, The Eightfold Way, Benjamin, New York, (1964)

[2] S. Okubo, Prog. Theor. Phys. **27**, 949 (1962)

[3] G. N. Shah and T. A. Mir, Mod. Phys. Lett. A, **23**, 53 (2008)

[4] D. Diakanov et al., Z. Phys. A, **359**, 305 (1997).

[5] R. Jafe and F. Wilczek, Phys. Rev. Lett., **91**, 252001 (2003)

[6] C. Alt et al., Phys. Rev. Lett., **92**, 042003 (2004)

[7] V. Kuznetsova et al., Acta. Phys. Polo. B, **39**, 1949 (2008)