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Sum Rule of Charmed Baryon Masses in Null-Instanton Model

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An ambiguity of baryon mass formula in a null-instanton model is solved. The role of the null-instanton ball in hadronic weak interaction is discussed.

Recently magnetic moments of baryons in the null-instanton model[1] have obtained some attention.[2),3)] We have given the baryon mass formula in the null-instanton model[4] where there arose an ambiguity in the choice of the effects, viz., asymmetric and symmetric (abbreviated as A and S hereafter) type, when the three composite valence-quarks are different.

The purpose of this paper is to solve at first this ambiguity from the mass sum rule on baryons. Secondly, the simultaneous S-wave virtual production of an odd number of null-instanton $q'\bar{q}$ balls in the quark matter will induce the additional parity violation in the weak decay of the bound quark.

Let us summarize the relevant mass formula for the spin and parity 1/2+ baryons by making use of their symbols for short. They are given by

$$N = 3U-\frac{3}{2}\alpha,\ \Lambda = S+2U-\alpha-\frac{1}{2}\beta,\ \Sigma = S+2U-\frac{3}{2}\beta,\ \Xi = 2S+U-\frac{3}{2}\beta,$$

$$\Lambda_c = C+2U-\alpha-\frac{1}{2}\gamma,\ \Sigma_c = C+2U-\frac{3}{2}\gamma,\ (\Xi_c)_{A,S} = C+S+U-\frac{3}{2}(\beta,\gamma,\delta)_{A,S},$$

$$\text{and}\quad \Omega_c = C+2S-\frac{3}{2}\delta, \tag{1}$$

where U, S and C are the effective u- (d-), s- and c-quark mass, respectively. Additional 4 parameters α, β, γ and δ arise from the null-instanton $q'\bar{q}$ ball rule for composite quarks. Their origin will be seen from their correspondence in each mass formula. Here the symbols

$$(a,b,c)_A = \frac{1}{6}(4a+b+c) \quad\text{and}\quad (a,b,c)_S = \frac{1}{3}(a+b+c) \tag{2}$$

are introduced for simplicity.

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There are totally seven parameters and eight observed masses,[5] so one can construct at least one sum rule from them. We find two sum rules corresponding to A and S type Ξ_c-baryon. Each of them splits into a sum rule among 7 masses and the well known Gell-Mann-Okubo one. We give the new ones for each type by

$$4N + 8\Xi + 6\Lambda_c + \Omega_c - 12\,\Lambda - \Sigma_c - 6\,(\Xi_c)_A = 0 \qquad (3)$$

$$(30714 - 30654 = \pm(11\text{-}21))\ \text{MeV},$$

$$2N + 4\Xi + 3\Lambda_c + \Sigma_c + 2\,\Omega_c - 6\Lambda - 6\,(\Xi_c)_S = 0 \qquad (4)$$

$$(21866\text{-}21502 = \pm(11\text{-}21))\ \text{MeV},$$

respectively. One learns from these results that the A-type choice is better. In order to check this conclusion the other way, we have solved coupled 4 charmed baryon mass formulas under the four free parameters C, β, γ and δ, by fixing remaining three parameters to U=415.453, S= 556.477, α = 205.140 MeV found from the light-baryon study.[4] We find common C=1677.5, γ =37.1 and δ = 59.0 MeV, but β = 158.5 and 269.0 MeV for type A and S, respectively. The former type is closer to the one β=131.7 MeV found in the light-baryon study. From these results we conclude that the A-type null-instanton contribution is favored for charmed baryons.

There is one confirmed Λ_b baryon.[5] This data, the empirical rules for instanton induced potential energies $S(b\bar{u}) = 3\,\varepsilon$, $S(b\bar{s}) = 3\,\varsigma$ and two combinations of the 0^- and 1^- B and B_s meson mass formulas are used to determine the additional parameters. Notice that the rule is an extension made parallel to the definition of the null-instanton potentials between two quarks in baryons and holds approximately true for light-mesons. Let us rely on this empirical rule in order to derive parameter values from b-associated meson masses.

$$B^* - B = 3\,\varepsilon \quad \text{and} \quad B_s^* - B_s = 3\,\varsigma\,. \qquad (5)$$

One finds ε = 15.3 and ς =15.7 MeV. Making use of the same symbol B as an effective b-quark mass one finds

$$\Lambda_b = B + 2U - \alpha - \frac{1}{2}\varepsilon\,. \qquad (6)$$

One gets B = 5006 MeV. The mass formulas of the following five bottomed baryons will be found in ref.[4] Some of them contain parameters γ and δ in addition. We shall give only their predicted masses for short. Σ_b = 5814, $\Xi(usb)_A$ = 5812, $\Omega(ssb)$ = 6097, $\Xi(ubb)$ = 10400 and $\Omega(sbb)$ = 10550 MeV.

One more interesting object is the charmed B-meson B_c. In our model we find

$$B_c = B + C - V(b\bar{c}) - S(b\bar{c}). \qquad (7)$$

Here two new potential energy parameters appear. We predicts B_c =6200-6500 MeV by choosing V+S= 180-480 MeV based on our past experience, e.g., see Table II in ref.[4] The experimental value[6] is 6400± 390(stat.)± 130(syst.) MeV. The null-instanton model seems to be valid up to the bottomed hadron region, as far as the presently available data concern.

We should like to emphasize that the null-instanton model holds rather well irrespective to the composites in hadrons. Above all its beauty is very welcome in a unified point of view.

It is too bold to propose that the parity violation occurs through the S-wave virtual production of an odd number of null-instanton balls $q'\bar{q}$'s in the quark matter. However, once the weak interaction is started, the instantaneous nature of the null-instanton effect will admits the occurrence of above phenomena in the quark matter before the emission of the decay products. We think that the effect is at least collaborative to the weak interaction. This is reflected to the fact that the larger energy release in weak decay becomes the more enhancement of the CP (T) violation occurs as observed through the bound d (u) and s decays. The detailed study of K_S^0 -K_L^0 transition rate in the matter will give us an information on the null-instanton exchange potential in weak interaction between quarks belonging to the different hadrons.

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