On the nature of the newly discovered Ω states

S. S. Agaev¹, K. Azizi² and H. Sundu³

1 Institute for Physical Problems, Baku State University - Az-1148 Baku, Azerbaijan
2 Department of Physics, Doğuş University - Acıbadem-Kadıköy, 34722 Istanbul, Turkey
3 Department of Physics, Kocaeli University - 41380 İzmit, Turkey

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Abstract - The mass and residue of the ground-state, as well as the first orbital and radial excitations of the heavy Ω_c baryons with Q = b or c quark, for both J = 1/2 and J = 3/2 are calculated by means of the QCD two-point sum rule method using the general forms for the interpolating currents. In the calculations the quark, gluon and mixed vacuum condensates up to ten dimensions are taken into account. We compare our results for the masses of Ω_c− and Ω_c0 baryons with the existing predictions of other theoretical works. Our results for the charmed baryons are confronted with the experimental data of the LHCb Collaboration to understand the nature of the recently observed narrow Ω_c0 resonances. The predictions for the masses of the Ω_c− baryons with the same quantum numbers may shed light on future experimental searches for the corresponding bottom baryons.

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Exploration of heavy flavored baryons, that is baryons containing one or two heavy quarks, has become one of the interesting areas of high-energy physics. Experimental collaborations have started to inform on new observations of these particles and measurements of their parameters [1]. It seems that in the near future we will witness a rapid growth of intriguing discoveries.

The Ω_c0 = [cşś] and Ω_c− = [bss] particles belong to a class of the baryons with one heavy quark. Till now the experimental information on the spectrum of the Ω_c baryons was limited by the Ω_c0 and Ω_c(2770)0 particles with masses [2]

\[ m = 2695.2 \pm 1.7 \text{ MeV}, \quad m = 2765.9 \pm 2.0 \text{ MeV}. \] (1)

They are presumably the ground states Ω_c0 and Ω_c− with spin-parity J^P = 1/2^+ and J^P = 3/2^+, respectively. In the class of Ω_c− baryons the experimental measurement was restricted by the mass of Ω_c− with J^P = 1/2^+ (see ref. [2])

\[ m = 6071 \pm 40 \text{ MeV}. \] (2)

Recently, the LHCb Collaboration reported on the discovery of five narrow states Ω_c^1 in the Ξ^+K^- invariant-mass distribution based on the pp collision data at center-of-mass energies 7, 8 and 13 TeV with an integrated 3.3 fb^-1 luminosity [3] The masses of the Ω_c^1 states were measured and found to be equal to (in MeV) M = 3000; 3050; 3066; 3090; 3119. The LHCb determined also their widths through Ω_c^1 \to Ξ^+K^- decay channels, which did not exceed a few MeV.

Theoretical investigations of the heavy flavored baryons, on the contrary embrace a variety of models and methods. The spectra of the ground and excited states of the charmed and bottom baryons were analyzed in the context of the QCD sum rule method [4–14], different relativistic and non-relativistic quark models [15–23], the Heavy Quark Effective Theory (HQET) [24], and in lattice simulations [25]. The masses and magnetic moments, radiative decays, various strong couplings and transitions of the heavy flavored baryons were the subject of rather intensive theoretical studies, as well [26–32]. Some of these theoretical works were carried out using additional assumptions on the structure of the charmed and bottom baryons. For example, in the relativistic quark model they were considered as the heavy-quark-light-diquark bound states [16,17]. In other papers, QCD sum rule calculations aimed to evaluate spectroscopic parameters of the charmed baryons were performed in the framework of HQET [6,7,13,14].

A new experimental situation emerged due to the discovery of the LHCb Collaboration, necessitates a more detailed investigation of charmed and bottom baryons and their spectra. In the present letter we will calculate the mass and pole residue of the ground-state, as well as the...
first orbital and radial excitations of the heavy flavored spin-1/2 and -3/2 baryons in the framework of the QCD two-point sum rule approach by employing the most general form of the interpolating currents without any restricting suggestions about their internal organization. We are going to follow a scheme applied in refs. [33,34] to calculate the masses and residues of the radially excited octet and decuplet baryons. In these works, the authors got results, which are compatible with existing experimental data on the masses of the radially excited baryons, and demonstrate that the QCD sum rule method besides ground-states baryons can be successfully applied to investigate their excitations, as well.

In order to derive the sum rules for the mass and residue of the spin-1/2 and spin-3/2 baryons we start from the two-point correlation function

$$\Pi_{\mu \nu}(p) = i \int d^4 x e^{i p x} \langle 0 | T \{ \eta_{\mu}(x) \bar{\eta}_{\nu}(0) \} | 0 \rangle,$$  

(3)

where $\eta(x)$ is the interpolating current for the baryons with $J = 1/2$. It is given by the expression

$$\eta = \frac{1}{2} e^{abc} \left\{ \left( s^a T C Q^b \right) \gamma_5 s^c + \beta \left( s^a T C \gamma_5 Q^b \right) s^c \right\} - \left\{ \left( s^a T C s^b \right) \gamma_5 s^c + \beta \left( Q^a T C \gamma_5 s^b \right) s^c \right\}.$$  

(4)

In the case of the spin-3/2 baryons the interpolating current $\eta_{\mu}$ has the form

$$\eta_{\mu} = \frac{1}{\sqrt{3}} e^{abc} \left\{ \left( s^a C \gamma_{\mu} s^b \right) Q^c + \left( s^a C \gamma_{\mu} Q^b \right) s^c \right\} + \left( Q^a C \gamma_{\mu} s^b \right) s^c.$$  

(5)

In the expressions above $C$ is the charge conjugation matrix. The current $\eta$ for the spin-1/2 baryons contains an arbitrary auxiliary parameter $\beta$, where $\beta = -1$ corresponds to the choice of the Ioffe current. It should be noted that the currents given by eqs. (4) and (5) couple not only to the ground-state and radial excitations (2S, 1/2$^+$) and (2S, 3/2$^+$), but also to their orbital excitations with quantum numbers (1P, 1/2$^-$) and (1P, 3/2$^-$), respectively.

The correlation function has to be calculated using both the physical and quark-gluon degrees of freedom. To this end, we adopt the “ground-state+1P+2S excitations+continuum” scheme and calculate $\Pi_{\text{Phys}}(p)$ in terms of the involved particles’ parameters

$$\Pi_{\text{Phys}}(p) = \frac{\langle 0 | \eta_{\mu} \Omega_Q | \Omega_Q \rangle | 0 \rangle}{m^2 - p^2} + \frac{\langle 0 | \eta_{\mu} \bar{\Omega}_Q | \bar{\Omega}_Q \rangle | 0 \rangle}{m^2 - p^2} + \frac{\langle 0 | \eta_{\mu} \bar{\Omega}_Q | \Omega_Q \rangle | 0 \rangle}{m^2 - p^2} + \ldots,$$  

(6)

where $\Omega_Q$, $\bar{\Omega}_Q$ and $\Omega_Q$ are the ground-state, first orbitally and radially excited baryons with masses $m$, $\tilde{m}$ and $m$, respectively. The dots stand for contribution of the higher excited states and continuum.

In order to proceed for the spin-1/2 baryons we introduce the matrix elements

$$\langle 0 | \eta_{\mu} \Omega_Q | \Omega_Q \rangle \langle 0 \rangle = \lambda^{(\mu)} u^{(\mu)}(p, s),$$

$$\langle 0 | \eta_{\mu} \bar{\Omega}_Q | \bar{\Omega}_Q \rangle \langle 0 \rangle = \lambda \tilde{\gamma}_5 \tilde{u}(p, s),$$

(7)

where $\lambda$ and $\lambda^\prime$ are the pole residues of the $\Omega_Q$, $\bar{\Omega}_Q$ and $\bar{\Omega}_Q$ states, respectively. Employing eqs. (6) and (7) and performing the summation over the spin of $J = 1/2$ baryons

$$\sum_s u(p, s) \bar{u}(p, s) = \phi + m,$$  

(8)

we get

$$\Pi_{\text{Phys}}(p) = \frac{\lambda^2 (\phi + m)}{m^2 - p^2} + \frac{\overline{\lambda}^2 (\phi - \tilde{m})}{m^2 - p^2} + \frac{\lambda^2 (\phi + m')}{m^2 - p^2} + \ldots.$$  

(9)

The Borel transformation applied to eq. (9) leads to the result

$$B \Pi_{\text{Phys}}(p) = \lambda^2 e^{-\frac{m^2}{\lambda^2}} (\phi + m) + \overline{\lambda}^2 e^{-\frac{m^2}{\overline{\lambda}^2}} (\phi - \tilde{m}) + \lambda^2 e^{-\frac{m^2}{m^2}} (\phi + m').$$  

(10)

As is seen, there are two structures in eq. (10), namely $\sim \phi$ and $\sim m$, both of which can be utilized to derive the required sum rules

$$\lambda^2 e^{-\frac{m^2}{\lambda^2}} + \overline{\lambda}^2 e^{-\frac{m^2}{\overline{\lambda}^2}} + \lambda^2 e^{-\frac{m^2}{m^2}} = B \Pi_{\text{Phys}}^0(p),$$

$$\lambda^2 m e^{-\frac{m^2}{\lambda^2}} - \overline{\lambda}^2 m e^{-\frac{m^2}{\overline{\lambda}^2}} + \lambda^2 m' e^{-\frac{m^2}{m^2}} = B \Pi_{\text{Phys}}^1(p),$$

(11)

where $B \Pi_{\text{Phys}}^0(p)$ and $B \Pi_{\text{Phys}}^1(p)$ are the Borel transformation of the corresponding structures in $\Pi(p)$, but calculated in terms of the quark-gluon degrees of freedom and labeled as $\Pi^0_{\text{Phys}}(p)$. Here we refrain from writing down the rather lengthy expressions of the functions $B \Pi^1_{\text{Phys}}(p)$ and $B \Pi^2_{\text{Phys}}(p)$, which will be published elsewhere.

In the case of the $J = 3/2$ baryons we use the matrix elements

$$\langle 0 | \eta_{\mu} | \Omega_Q \rangle \langle 0 \rangle = \lambda^{(\mu)} u^{(\mu)}(p, s),$$

$$\langle 0 | \eta_{\mu} | \bar{\Omega}_Q \rangle \langle 0 \rangle = \tilde{\lambda} \tilde{\gamma}_5 \tilde{u}(p, s),$$

(12)

where $u_{\mu}(p, s)$ are the Rarita-Schwinger spinors, and perform the summation over the spin of the baryons by means of the formula

$$\sum_s u_{\mu}(p, s) \bar{u}(p, s) = \left( \phi + m \right) \left( \bar{g}_{\mu\nu} - \frac{1}{3} \gamma_{\mu} \gamma_{\nu} \right) + \frac{2}{3 m^2} p_{\mu} p_{\nu} + \frac{1}{3 m} (p_{\mu} \gamma_{\nu} - p_{\nu} \gamma_{\mu}) + \ldots.$$  

(13)

The interpolating current $\eta_{\mu}$ couples to the spin-1/2 baryons with both parities, as well. Their contributions
can be separated and removed from the sum rules by special ordering of the Dirac matrices (see, for example ref. [33]). It is not difficult to demonstrate, that the terms, which are formed exclusively due to contribution of the 3/2 baryons are proportional to the structures \( \sim p g_{\mu \nu} \) and \( \sim g_{\mu \nu} \). Namely, these structures and corresponding invariant amplitudes are employed to get sum rules for the masses and pole residues of the ground-state and excited spin-3/2 charmed and bottom baryons.

The correlation function \( \Pi^{\text{OPE}}(p) \) should be found using the general expression eq. (3) and heavy and light quarks' propagators. In calculations we employ the s-quark and heavy-quark propagators given by the expressions

\[
S_s^{ab}(x) = i \delta_{ab} \frac{x}{2 \pi^2 x^4} - \delta_{ab} \frac{m_s}{4 \pi^2 x^2} - \delta_{ab} \left( \frac{s s}{12} \right) \\
+ i \delta_{ab} \frac{x^2 f_{m_s} \langle s s \rangle}{48} - \delta_{ab} \frac{x^2}{192} \langle s g_s, G_s \rangle + i \delta_{ab} \frac{x^2 f_{m_s}}{1152} \\
\times \left( \langle s g_s, G_s \rangle - \frac{g_s G_{s \beta}^\beta}{2 \pi^2 x^2} \right) \left[ \rho_{\sigma \alpha \beta} + \sigma_{\alpha \beta} f \right] \\
- i \delta_{ab} \frac{x^2 f_{g_s}^{2 \prime} \langle s s \rangle}{7776} - \delta_{ab} \frac{x^4 \langle s s \rangle \langle g_s G_s^\alpha \rangle}{27648} + \ldots
\]

(14)

and

\[
S_Q^{ab}(x) = \int \frac{d^4k}{(2\pi)^4} e^{-ikx} \left\{ \frac{\delta_{ab} (k + m_Q)}{k^2 - m_Q^2} - \frac{g_s G_{ab}^{\alpha \beta} \rho_{\sigma \alpha \beta} (k + m_Q) + (k + m_Q) \sigma_{\alpha \beta}}{4 (k^2 - m_Q^2)^2} \right. \\
\left. + \frac{g_s^2 G_{ab}^{2 \prime}}{12} \delta_{ab} m_Q \frac{k^2 + m_Q^2}{(k^2 - m_Q^2)^2} + \ldots \right\}.
\]

(15)

The correlation functions \( \Pi_{1(2)}^{\text{OPE}}(p) \) can be written down in the form

\[
\Pi_{1(2)}^{\text{OPE}}(p) = \int_{(m_Q + 2m_s)^2} \frac{d\rho_{1(2)}^{\text{QCD}}(s)}{s - p^2},
\]

(16)

where \( \rho_{1(2)}^{\text{QCD}}(s) \) are the corresponding spectral densities, and \( s_0 \) is the continuum threshold parameter. In eq. (16) contribution of the higher excited states and continuum is subtracted using the quark-hadron duality assumption.

As is seen, the sum rules for the mass and residue of the ground-state and excited baryons contain parameters all of the particles involved into analysis. We have evaluated the mass and pole residue of the ground-state 1/2+ baryons by employing the two-point sum rule method within the “ground-state + continuum” scheme. Then the excited states (1P, 1/2+) and (2S, 1/2+) belong to the continuum. At the next step we use \((m, \lambda)\) as input parameters to fix \((m_\omega, \lambda)\). At the last phase of computations we determine parameters \((m', \lambda')\) of radially excited state \((2S, 1/2+)\) by treating \((m, \lambda)\) and \((m_\omega, \lambda)\) as known inputs. In calculations the vacuum condensates up to ten dimensions are taken into account. By the same way one can derive equations to evaluate the parameters of the spin-3/2 baryons.

The sum rules depend on numerous parameters which are collected in table 1. It contains the masses of the bottom, charm and strange quarks, as well as quark, gluon and mixed vacuum condensates. The sum rules also require fixing of the working windows for the Borel parameter \( M^2 \) and continuum threshold \( s_0 \), which are two auxiliary parameters of the calculations. For the spin-1/2 particles we have additionally the \( \beta \) parameter coming from the expression of the interpolating current. The choice of \( M^2, s_0, \beta \) is not totally arbitrary, but should satisfy the standard restrictions of the sum rule calculations. Namely, the convergence of the operator product expansion, dominance of the pole contribution, existence of the \((M^2, s_0)\) regions, where dependence of the extracted quantities on \( M^2 \) and \( s_0 \) is minimal, have to be obeyed. The same is true for \( \beta \); we have to determine a working region for \( \beta \) by demanding a weak dependence of our results on its choice.

Predictions obtained in this work for the masses and pole residues of the 1S, 1P and 2S bottom baryons with \( J = 1/2 \) and \( J = 3/2 \), as well as the working ranges of the parameters \( M^2 \) and \( s_0 \) are shown in table 2. Results for the spin-1/2 baryons are obtained by varying the parameter \( \beta = \tan \theta \) in eq. (4) within the limits

\[
-0.75 \leq \cos \theta \leq -0.45, \quad 0.45 \leq \cos \theta \leq 0.75,
\]

(17)
to achieve the stable sum rules’ predictions. Here we provide also theoretical errors of our predictions stemming mainly from uncertainties in the choice of the auxiliary parameters \( M^2 \) and \( s_0 \) (for spin-1/2 baryons from \( \beta \) parameter, as well). For the masses of the baryons these errors are less than for their residues. The reason behind of this feature is well known: in fact, sum rules for the masses are given by a ratio of terms containing integrals of the spectral densities \( \rho_{1(2)}(s) \), \( sp_{1(2)}(s) \), which considerably reduces effects of involving errors. Calculation of the spectral densities \( \rho_{1(2)}(s) \) by taking into account vacuum condensates up to tenth dimensions also improves an accuracy of performed analysis. Nevertheless, errors in computations of the residues are significant, and for the charmed

| Parameter | Value |
|-----------|-------|
| \( m_\rho \) | 4.18^{+0.06}_{-0.04} \text{ GeV} |
| \( m_c \) | (1.27 \pm 0.03) \text{ GeV} |
| \( m_s \) | 96^{+4}_{-4} \text{ MeV} |
| \( \langle q \bar{q} \rangle \) | -0.24^{+0.01}_{-0.03} \text{ GeV}^3 |
| \( \langle s s \rangle \) | 0.8 \langle q \bar{q} \rangle |
| \( m_0^2 \) | (0.8 \pm 0.1) \text{ GeV}^2 |
| \( \langle s g_s, G_s \rangle \) | \( m_0^2 \langle s s \rangle \) |
| \( \langle s G_s^2 \rangle \) | (0.012 \pm 0.004) \text{ GeV}^4 |

Table 1: The Parameters used in the numerical computations.
Table 2: The \( m_{\Omega} \) and \( \lambda_{\Omega} \) of the ground-state and excited bottom baryons with \( J = 1/2 \) and \( J = 3/2 \).

| \( (n, J^P) \) | \( (1S, \frac{1}{2}^+) \) | \( (1P, \frac{1}{2}^-) \) | \( (2S, \frac{3}{2}^+) \) | \( (1S, \frac{3}{2}^+) \) | \( (1P, \frac{3}{2}^-) \) | \( (2S, \frac{5}{2}^+) \) |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| \( M^2 \) (GeV\(^2\)) | 6.5 – 9.5 | 6.5 – 9.5 | 6.5 – 9.5 | 6.5 – 9.5 | 6.5 – 9.5 | 6.5 – 9.5 |
| \( s_0 \) (GeV\(^2\)) | 3.0 – 3.2 | 3.3 – 3.5 | 3.5 – 3.7 | 3.1 – 3.3 | 3.4 – 3.6 | 3.6 – 3.8 |
| \( m_{\Omega} \) (MeV) | 2685 ± 123 | 2990 ± 129 | 3075 ± 142 | 2769 ± 89 | 3056 ± 103 | 3119 ± 108 |
| \( \lambda_{\Omega} \cdot 10^2 \) (GeV\(^3\)) | 6.2 ± 1.8 | 11.9 ± 2.8 | 17.1 ± 3.4 | 7.1 ± 1.0 | 16.1 ± 1.8 | 25.0 ± 3.1 |

Table 3: The various theoretical predictions for masses of the spin-1/2 and -3/2 bottom baryons.

| \( \Omega_b(1S, \frac{1}{2}^+) \) (MeV) | \( \hat{\Omega}_b(1P, \frac{1}{2}^-) \) (MeV) | \( \Omega_b^*(2S, \frac{1}{2}^+) \) (MeV) | \( \Omega_b^*(1S, \frac{3}{2}^+) \) (MeV) | \( \hat{\Omega}_b^*(1P, \frac{3}{2}^-) \) (MeV) | \( \Omega_b^*(2S, \frac{3}{2}^+) \) (MeV) |
|----------------|----------------|----------------|----------------|----------------|----------------|
| 6024 ± 157 | 6336 ± 183 | 6487 ± 187 | 6084 ± 161 | 6301 ± 193 | 6422 ± 198 |
| 6064 | 6330 | 6450 | 6088 | 6340 | 6461 |
| 6056 | 6340 | 6479 | 6079 | | 6493 |
| 6081 | 6301 | 6472 | 6102 | 6304 | 6478 |
| 6130 ± 120 | – | – | 6060 ± 130 | – | – |

Table 4: The sum rule results for the parameters of 1S, 1P and 2S spin-1/2 and -3/2 charmed baryons calculated in the context of the different approaches.

| \( (n, J^P) \) | \( (1S, \frac{1}{2}^+) \) | \( (1P, \frac{1}{2}^-) \) | \( (2S, \frac{1}{2}^+) \) | \( (1S, \frac{3}{2}^+) \) | \( (1P, \frac{3}{2}^-) \) | \( (2S, \frac{3}{2}^+) \) |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| \( M^2 \) (GeV\(^2\)) | 3.5 – 5.5 | 3.5 – 5.5 | 3.5 – 5.5 | 3.5 – 5.5 | 3.5 – 5.5 | 3.5 – 5.5 |
| \( s_0 \) (GeV\(^2\)) | 3.0 – 3.2 | 3.3 – 3.5 | 3.5 – 3.7 | 3.1 – 3.3 | 3.4 – 3.6 | 3.6 – 3.8 |
| \( m_{\Omega} \) (MeV) | 2685 ± 123 | 2990 ± 129 | 3075 ± 142 | 2769 ± 89 | 3056 ± 103 | 3119 ± 108 |
| \( \lambda_{\Omega} \cdot 10^2 \) (GeV\(^3\)) | 6.2 ± 1.8 | 11.9 ± 2.8 | 17.1 ± 3.4 | 7.1 ± 1.0 | 16.1 ± 1.8 | 25.0 ± 3.1 |

Table 5: The theoretical predictions for masses of the ground-state, first orbitally and radially excited spin-1/2 and -3/2 charmed baryons.

| \( \Omega_b(1S, \frac{1}{2}^+) \) (MeV) | \( \hat{\Omega}_b(1P, \frac{1}{2}^-) \) (MeV) | \( \Omega_b^*(1S, \frac{3}{2}^+) \) (MeV) | \( \hat{\Omega}_b^*(1P, \frac{3}{2}^-) \) (MeV) | \( \Omega_b^*(2S, \frac{3}{2}^+) \) (MeV) |
|----------------|----------------|----------------|----------------|----------------|
| 2685 ± 123 | 2990 ± 129 | 3075 ± 142 | 2769 ± 89 | 3056 ± 103 |
| 2698 | 2966 | 3088 | 2768 | 3054 | 3123 |
| 2699 | 3035 | 3159 | 2767 | | 3202 |
| 2718 | 2977 | 3152 | 2776 | 2986 | 3190 |
| 2720 ± 180 | – | – | 2760 ± 100 | – | – |

Baryons vary from 11% till 29%; these uncertainties are unavoidable part of sum rule computations, and may reach 30% of a whole result.

Our prediction for the mass of the \( \Omega_b(1S, \frac{1}{2}^+) \) baryon within both the experimental and theoretical errors is in reasonable agreement with the measurement (2). In table 3 we confront our results for the bottom baryons with theoretical calculations performed within various models. As is seen, previous analysis of the \( \Omega_b \) baryons made in the framework of the sum rule method in refs. [9,10] was limited by the parameters of the ground-state \( \Omega_b(1S, \frac{1}{2}^+) \) and \( \Omega_b^*(1S, \frac{3}{2}^+) \). Our present calculations embrace parameters not only for the ground-state, but also first orbitally and radially excited states, and are essential extension of existing theoretical predictions obtained using the sum rule method. They are in accord with available theoretical results extracted in refs. [17,19,20] employing other methods, as well.

The results for the parameters of \( \Omega_b \) and \( \Omega_b^* \) baryons, as well as their masses obtained using alternative models, are collected in tables 4 and 5, respectively. Comparing our results for the ground states’ masses of \( m_{\Omega_b} \)
and $m_{\Omega_c}$ with the experimental data given in eq. (1), we find a nice agreement between them. Our predictions on the masses of the charmed baryons allow us to interpret the resonances $\Omega_c(3000)^0$, $\Omega_c(3050)^0$, $\Omega_c(3066)^0$ and $\Omega_c(3119)^0$, recently discovered by the LHCb Collaboration, as the first orbitally ($1P, 1/2^-$), ($1P, 3/2^-$) and radially excited ($2S, 1/2^+$), ($2S, 3/2^+$) charmed baryons, respectively. The analysis of the $\Omega_c^0$ baryons based on their masses and widths has been presented in our work [35]. The $\Omega_c^0$ baryons discovered by the LHCb Collaboration were also considered within the sum rule method in ref. [36], and were interpreted as $1P$-excitations of spin-1/2, -3/2 and -5/2 particles.

The LHCb Collaboration measured the masses and widths of five $\Omega_c^0$ states, but did not fix their spin-parities. Therefore, detailed and comprehensive experimental investigations of these resonances are required to clarify problems connected with their internal structure and quantum numbers, and make a choice between alternative theoretical models.

It is also evident that experimental studies of the heavy flavored baryons are in the agenda of different experimental collaborations and will be continued in the future. Our predictions for the ground-state, as well as the orbitally and radially excited $\Omega_c^0$ baryons with $J = 1/2$ and $J = 3/2$ provide valuable information on $b$-baryons, which, together with the results of alternative approaches, form a theoretical basis for these experiments and may help them in the course of the search for the bottom baryons.

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