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Mass spectra of triply heavy charm-beauty baryons

Zalak Shah[1,*] and *Ajay Kumar* Rai[1,**]

[1]Department of Applied Physics, Sardar Vallabhbhai National Institute of Technology

Abstract. We extract the mass spectra of triply heavy charm-beauty baryons using Hypercentral constituent quark model. The first order correction is also added to the potential term of Hamiltonian. The radial and orbital excited state masses are also determined. Moreover, the Regge trajectories and magnetic moments are also given for these baryons.

1 Introduction

The new states of heavy hadrons are identified by experimental groups very recently [1]. Also, many theoretical studies have been performed in the last decade. In the case of heavy baryons, we have singly, doubly and triply heavy baryons. They can be found in both charm and bottom sector. The Triply Ω baryons have considerable theoretical interest and they are the baryonic analogue of charmonia/bottomonia. In reference to the SU(3) symmetry, at the top most layer, three light quarks are replaced by the heavy quarks and we have Ω family. They are color-singlet bound states combined from three heavy charm/bottom quarks. The family members are Ω_{ccc}, Ω_{bbb}, Ω_{ccb} and Ω_{bbc} [2–4]. LHCb experiment possibly detect $\Omega_{bbb}, \Omega_{bbc}, \Omega^*_{bbc}$ baryons at appropriate integrated luminosity and collision energy [5] in near future. In present paper, we will study the the triply heavy charm-beauty baryons. We use Hypercentral Constituent quark model with Coulomb plus linear potential (see Sect. 2). We determine the ground state, radial and orbital excited states masses of $\Omega_{bbc}, \Omega_{ccb}$ baryons. Moreover, we plot Regge trajectories of this baryons and calculate the magnetic moments at L=0. (see Sect. 3)

2 Methodology

We employ the Hypercentral Constituent quark Model(hCQM) with Coulomb plus linear confinement potential and also added first order correction for the quarks [6–10]. The relative Jacobi coordinates can be expressed as [11, 12]

$$\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r_1} - \vec{r_2}), \qquad \vec{\lambda} = \frac{m_1\vec{r_1} + m_2\vec{r_2} - (m_1 + m_2)\vec{r_3}}{\sqrt{m_1^2 + m_2^2 + (m_1 + m_2)^2}} \tag{1}$$

The Hamiltonian of the baryonic system in the hCQM is then expressed as

$$H = \frac{P_x^2}{2m} + V(x). \tag{2}$$

[*]e-mail: zalak.physics@gmail.com
[**]e-mail: raiajayk@gmail.com

Table 1. Ground state masses of triply heavy baryons (in GeV)

	Baryons	Ω_{ccc}^{++}	Ω_{bbb}^{-}	Ω_{bbc}^{0}		Ω_{ccb}^{+}	
Method	J^P	$\frac{3}{2}^+$	$\frac{3}{2}^+$	$\frac{1}{2}^+$	$\frac{3}{2}^+$	$\frac{1}{2}^+$	$\frac{3}{2}^+$
Hypercentral Model	Our work	4.806	14.496	11.231	11.296	8.005	8.049
Variational cornell	[14]	4.799	14.398	11.214	11.245	8.018	8.046
di-quark Model	[15]	4.760	14.370	11.277	11.284	8.005	8.027
Sum rule	[16]	4.990	14.830	11.50	11.490	8.230	8.230
Relat. quark model	[17]	4.803	14.569	11.280	11.287	8.018	8.025
Lattice	[18]	4.796	14.366	11.195	11.229	8.007	8.037

where, $m = \frac{2m_\rho m_\lambda}{m_\rho + m_\lambda}$, is the reduced mass and x is the six dimensional radial hyper central coordinate of the three body system. The quark masses m_c and m_b are 1.275 and 4.67 GeV. The model is formed by a linear confining interaction with a spin, flavor and orbital angular momentum dependent hyperfine interaction. The potential is in form of,

$$V(x) = V^0(x) + \left(\frac{1}{m_\rho} + \frac{1}{m_\lambda}\right) V^{(1)}(x) + V_{SD}(x). \tag{3}$$

The description of all the terms can be found in Refs. [2–4, 6–10, 13].

Table 2. Excited state masses of Ω_{bbc} and Ω_{ccb} baryons (in GeV). A and B are the masses without coreection and with first order correction to the potential.

State	A Ω_{bbc}	B	[19]	[20]	[21]	A Ω_{ccb}	B	[19]	[20]	[21]
2S($\frac{1}{2}^+$)	11.749	11.757	11.787			8.611	8.621	8.537		
3S($\frac{1}{2}^+$)	12.246	12.261				9.203	9.224			
4S($\frac{1}{2}^+$)	12.738	12.761				9.792	9.823			
5S($\frac{1}{2}^+$)	13.228	13.258				10.379	10.424			
2S($\frac{3}{2}^+$)	11.772	11.779	11.798			8.627	8.637	8.553		
3S($\frac{3}{2}^+$)	12.257	12.272				9.211	9.232			
4S($\frac{3}{2}^+$)	12.745	12.767				9.797	9.828			
5S($\frac{3}{2}^+$)	13.232	13.262				10.421	10.424			
$(1^4P_{1/2})$	11.561	11.573	11.710		11.62	8.388	8.400	8.418		8.36
$(1^4P_{3/2})$	11.554	11.566	11.711	11.5	11.62	8.372	8.383	8.420	8.35	8.36
$(1^4P_{5/2})$	11.547	11.558	11.762			8.354	8.365	8.432		
$(1^4D_{1/2})$	11.918	11.934				8.828	8.848			
$(1^4D_{3/2})$	11.911	11.928				8.810	8.831			
$(1^4D_{5/2})$	11.902	11.919	11.823			8.788	8.808	8.568		
$(1^4D_{7/2})$	11.891	11.909	11.810			8.760	8.780			
$(1^4F_{3/2})$	12.264	12.289				9.250	9.280			
$(1^4F_{5/2})$	12.254	12.278				9.225	9.254			
$(1^4F_{7/2})$	12.241	12.264				9.193	9.222			
$(1^4F_{9/2})$	12.226	12.249				9.156	9.184			

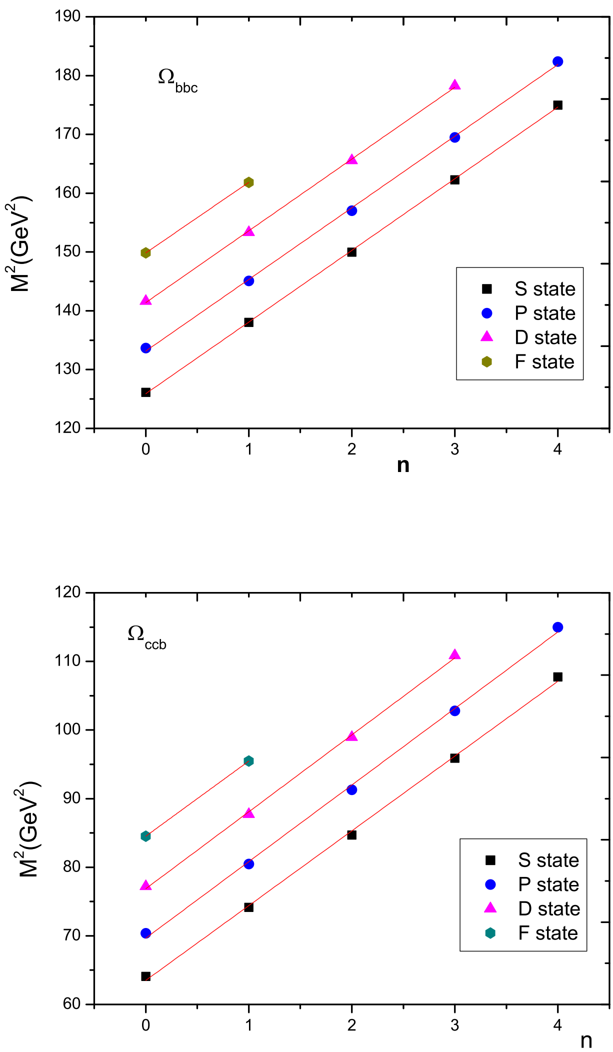

Figure 1. Regge Trajectories in (n, M^2) plane for charm-beauty triply heavy baryons [3, 4].

3 Results and Discussions

The ground state masses of triply heavy baryons are calculated for $J^P = \frac{1}{2}^+, \frac{3}{2}^+$. The obtained masses are near to the Refs. [14–18] (see Table 1). The radial excited states are calculated from 2S-5S with J^P values $\frac{1}{2}^+ \& \frac{3}{2}^+$ (see Table 2). The orbital excited states; 1P, 1D and 1F are shown with their respective J^P values in Table 2.

The rest state masses are shown in the form of Regge Trajectories. (see figure 1). As we know, the triply heavy baryons are still experimentally unknown. These trajectories are very helpful for the future predictions [22]. The plots are drawn in (n, M^2) plane. Where, n is a pricipal quantum number. The S, P, D and F states are with the J^P values $\frac{1}{2}^+$, $\frac{3}{2}^-$, $\frac{5}{2}^+$ and $\frac{7}{2}^-$, respectively. We can found them linear, parallel and equidistant.

The magnetic moments of baryons are obtained in terms of the spin, charge and effective mass of the bound quarks as in Ref.[8]

$$\mu_B = \sum_i \langle \phi_{sf} | \mu_{iz} | \phi_{sf} \rangle); \quad \mu_i = \frac{e_i \sigma_i}{2 m_i^{eff}}; \quad m_i^{eff} = m_i \left(1 + \frac{\langle H \rangle}{\sum_i m_i} \right) \tag{4}$$

where e_i is a charge and σ_i is the spin of the respective constituent quark.
The magnetic moment of Ω^+_{ccb} and Ω^{*+}_{ccb} are 0.606 and 0.819, respectively. The magnetic moment of Ω^+_{bbc} and Ω^{*+}_{bbc} are -0.233 and 0.228, respectively. These values are in good agreement with [15, 23–25].

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References

[1] M. Tanabashi et al. (Particle Data Group), Phys. Rev. D **98**, 030001 (2018).
[2] Z. Shah and A. K.Rai, Eur. Phys. J. A **53**, 195 (2017); PoS Hadron2017 **068** (2018).
[3] Z. Shah and A. K.Rai, Few Body Syst. **59**, 76 (2018).
[4] Z. Shah and A. K.Rai, Chin.Phys. C **42**, 053101 (2018).
[5] Y.Q. Chen, S.Z. Wu, JHEP **08**, 144 (2011).
[6] Z. Shah, K. Thakkar, A. K. Rai, and P. C. Vinodkumar, Eur. Phys. J. A **52**, 313 (2016).
[7] Z. Shah, K. Thakkar, A. K. Rai, and P. C. Vinodkumar,Chin. Phys. C **40**, 123102 (2016).
[8] Z. Shah and A. K. Rai, Eur. Phys. J. C **77**, 129 (2017).
[9] K. Thakkar, Z. Shah, A. K. Rai, and P. C. Vinodkumar, Nucl. Phys. A **965**, 57 (2017).
[10] Z. Shah and A. K. Rai, Few Body Syst. **59**, 112 (2018).
[11] M. Aiello, M. Ferraris, M. Giannini, M. Pizzo, and E. Santopinto, Phys. Lett. B **387**, 215 (1996).
[12] R. Bijker, F. Iachello, and A. Leviatan, Annals Phys. 284, 89 (2000).
[13] Z. Shah, A.K.Rai, *arXiv:1812.048* (2018).
[14] J.M. Flynn, E. Hernandez, J. Nieves, Phys. Rev. D **85**, 014012 (2012).
[15] K. Thakkar, A. Majethiya, P.C. Vinodkumar, Eur. Phys. J. Plus **131**, 339 (2016).
[16] Z.F. Sun, Z.W. Liu, X. Liu, S.L. Zhu, Phys. Rev. D **91**, 094030 (2015).
[17] A.P. Martynenko, Phys. Lett. B **663**, 317 (2008)
[18] Z.S. Brown, W. Detmold, S. Meinel, K. Orginos, Phys. Rev. D **90**, 094507 (2014).
[19] W. Roberts, M. Pervin, Int. J. Mod. Phys. A **23**, 2817 (2008).
[20] T. M. Aliev et al., J. Phys. G **41**, 065003 (2014).
[21] Z.G. Wang, Commun. Theor. Phys. **58**, 723 (2012).
[22] A. K. Rai, Z. Shah, J. Phys. Conf. Ser. **934**, 012035 (2017).
[23] A. Bernotas *et al.*, Lith. J. Phys. **53**, 84 (2013).
[24] R. Dhir and R. C. Verma, Eur. Phys. J. A **42** 243 (2009); Phys. Rev. D **88** 094002 (2013).
[25] B. Patel *et al.*, J. Phys. G **35**,065001(2008).