# SPECTROSCOPY OF HEAVY FLAVORED BARYONS

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## Introduction

The worldwide experiments such as LHCb, BELLE, BARBAR, CDF, CLEO are main source of identification of heavy baryons so far [1] and especially LHCb and Belle experiments have provided the new excited states in heavy baryon sector very recently [2]. An overview to the current status of research in the field of baryon physics from an experimental and theoretical aspects with a view to provide motivation and scope for the present thesis. The present study covers the baryons with one heavy and two light quarks [3–5]; two heavy and one light quark as well as three heavy quarks [6–8]. Baryons containing heavy quark(s) offer an important role in manifesting the symmetries of QCD. SU(4) symmetrical group includes all of the baryons containing zero, one, two or three heavy $Q$ (charm or beauty) quarks with light u, d and s quarks. This multiplet structure is expected to be repeated for every combination of spin and parity which provides a very rich spectrum of baryonic states. The multiplet numerology three fundamental rendition represents totally symmetric 20-plet, the mixed symmetric $20^{'}$-plet and the total anti symmetric $\bar{4}$ multiplet. The ground levels of SU(4) group multiplets are SU(3) decuplet, octet, and singlet, respectively.

The bound state heavy baryons can be studied in the QCD motivated potential models treating to the non relativistic Quantum mechanics. It is interesting to identify the mass spectrum of heavy baryons in charm as well as bottom sector. The present study deals with the Hypercentral Constituent Quark Model(hCQM). This scheme accounts to an average two-body potential for the three quark system over the hyper angle using the relative Jacobi coordinates ($\vec{\rho}$ and $\vec{\lambda}$) [9]. The Hamiltonian is given by

$$H = \frac{P_x^2}{2m} + V(x). \qquad (1)$$

The potential is usually chosen in a way that short distances coincides with the weak coupling QCD one-gluon exchange Coulomb potential and in the long range it incorporates confinement.

$$V(x) = V^0(x) + \left(\frac{1}{m_\rho} + \frac{1}{m_\lambda}\right) V^{(1)}(x) + V_{SD}(x). \qquad (2)$$

This interaction potential consists of a central term $V^0(x)$, spin dependant part $V_{SD}(x)$ and first order correction $V^1(x)$ is also added [10]. The central part $V^0(x)$ is in terms of vector(Couloumb) plus scalar(confining) terms. The whole mass spectrum is generated with first order correction and without correction to the potential.

The singly heavy baryons made up of one heavy ($c$ or $b$) and two light ($u$, $d$,$s$) quarks. All the ground states with $J^P = \frac{1}{2}^+, \frac{3}{2}^+$ of singly heavy charm and bottom baryons have been detected experimentally fortunately; except $\Omega_b^{*0}$. Many excited states of singly heavy baryons are also known so far such as $\Lambda_c(2595)^+$, $\Lambda_c(2625)^+$, $\Lambda_c(2880)^+$,$\Lambda_c(2940)^+$, $\Lambda_c(2765)^+$, $\Lambda_c(2860)^+$, $\Sigma_c(2800)^{++,+,0}$, $\Xi_c(2645)^{+,0}$, $\Xi_c(2790)^{+,0}$, $\Xi_c(2815)^{+,0}$, $\Xi_c(2980)^{+,0}$, $\Xi_c(3055)^+$, $\Xi_c(3080)^{+,0}$, $\Xi_c^{'}(3123)^+$, $\Xi_c(2930)^0$, $\Omega_c^0(3000)$, $\Omega_c^0(3050)$, $\Omega_c^0(3066)$, $\Omega_c^0(3090)$ and $\Omega_c^0(3119)$, $\Omega_c^0(3188)$, $\Lambda_b(5912)^0$, $\Lambda_b(5920)^0$. The mass spectra of singly heavy baryons are calculated from s-wave to f-wave. The separate calculations have been performed for all isospin states

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*Electronic address: `zalak.physics@gmail.com` of all baryons. The obtained results are compared with other theoretical predictions and also with the experimental outcomes. Also, the weak semi-electronic decays are calculated by using obtained ground state masses of singly heavy Ω and Ξ baryons.

Moving towards the baryons having two and three heavy quark construction. We have two doubly heavy baryon families, Ξ and Ω; in which the two strange quarks of baryon combinations are replaced by the heavy quarks(c, b). The experimental evidence comes for doubly heavy $\Xi_{cc}^{+}$ and $\Xi_{cc}^{++}$ baryons by the SELEX and LHCb experiments so far. Rest of the baryons are still experimentally unknown. The mass spectra of three doubly heavy $\Omega_{cc}$, $\Omega_{bb}$ and $\Omega_{bc}$ with a combination of light quark $s$ and six doubly heavy Ξ combining cc, bb and bc with a light quark $u$ or $d$ are produced. For triply heavy Ω baryons; $\Omega_{ccc}$, $\Omega_{bbb}$, $\Omega_{bbc}$ and $\Omega_{ccb}$ are considered. We have performed the calculations for 1S-5S, 1P-4P, 1D-4D and 1F-2F states for all these above mentioned baryons. Our obtained results are compared with others and we also predict the range in which resonance could be exist.

The two important properties of hadron spectroscopy are Regge Trajectories and Magnetic moments. The excited state masses upto l=3 are computed for singly, doubly, triply heavy baryons in charm-bottom sector; using these masses we are able to construct Regge trajectories in (n, $M^2$) and (J, $M^2$) planes for all calculated baryons. We use natural($J^P = \frac{1}{2}^+$, $J^P = \frac{3}{2}^-$, $J^P = \frac{5}{2}^+$, $J^P = \frac{7}{2}^-$) and unnatural ($J^P = \frac{3}{2}^+$, $J^P = \frac{5}{2}^-$, $J^P = \frac{7}{2}^+$, $J^P = \frac{9}{2}^-$) parity masses for plotting the graphs of heavy baryons. We can extract the parameters like slopes and intercepts of the Regge trajectories for heavy baryonic states. They are helpful to identify the $J^P$ values of the unknown states mentioned above. The determination of states were easy through these plots. The electromagnetic properties are one of the essential key tools in understanding the internal structure and geometric shapes of hadrons. In the present study, the magnetic moments of heavy flavour baryons are computed based on the nonrelativistic hypercentral constituent quark model using the spin-flavour wave functions of the constituting quarks and their effective masses. The magnetic moment of baryons are obtained for all singly, doubly and triply heavy baryon systems for positive parity $J^P = \frac{1}{2}^+, \frac{3}{2}^+$. We are also going to study the light flavor baryons using same methodology [11].

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