A Comparison study of Mass spectra of Bc mesons in non relativistic Quark Models*

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Introduction

Our Model uses the NRQM formalism for the study of properties of bottomonium states using a Hamiltonian which has the heavy quark potential derived from the instanton vacuum depending on r, the inter quark distance. The heavy quark potential derived from the instanton ensemble rises linearly as the relative distance between the quark and anti quark increases and gets saturated. TIn this line B_c meson is of significance when compared to flavour symmetric $c\bar{c}$ and $b\bar{b}$ meson states because it is the only meson composed of a b-quark and $\bar{c}$ quark and is the first particle containing both b and c quarks [1–3].

Theoretical Background

In a potential model approach the entire dynamics of quarks in a meson is governed by a Hamiltonian has kinetic energy term (K) and a potential energy (V), that is [2],

$$V(\vec{r}) = V_{Q\bar{Q}}(\vec{r}) + V_{coul}(\vec{r}) + V_{conf}(\vec{r})$$
$$V_{Q\bar{Q}}(\vec{r}) = V_C(\vec{r}) + V_{SD}(\vec{r}).$$

i) **Instantons Potential**

Here $V_C(\vec{r})$ and $V_{SD}(\vec{r})$ are central and spin dependent potentials due to instanton vacuum respectively [9].
$V_C(\vec{r})$ is given by the following expression

$$V_C(\vec{r}) \simeq \frac{4\pi\bar{\rho}^3}{\bar{R}^4 N_c}\left(1.345\frac{r^2}{\bar{\rho}^2} - 0.501\frac{r^4}{\bar{\rho}^4}\right) \quad (1)$$

Here, $\bar{\rho} = \frac{1}{3}$ fm the average size of the instanton, $\bar{R} = 1$ fm the average separation between instantons and number of colors N_C is 3.

ii) **The One Gluon Exchange Potential**

The central part of the two body potential due to OGEP [4] is given by

$$V_{OGEP}(\vec{r}_{ij}) = \frac{\alpha_s}{4}\vec{\lambda}_i \cdot \vec{\lambda}_j \left[\frac{1}{r_{ij}} - \frac{\pi}{M_i M_j}\left(1 + \frac{2}{3}\vec{\sigma}_i \cdot \vec{\sigma}_j\right)\delta(r_{ij})\right] \quad (2)$$

The spin-spin interaction $V_{SS}(\vec{r})$, the spin-orbit coupling term $V_{LS}(\vec{r})$ and the tensor part $V_T(\vec{r})$ contribute to the spin dependent potential $V_{SD}(\vec{r})$;

The coulomb-like (perturbative) one gluon exchange part of the potential. with the strong coupling constant α_s and inter quark distance r. The confinement term represents the non perturbative effect of QCD which includes the spin-independent linear confinement term [39].

In our work, we have used the three-dimensional harmonic oscillator wave function which has been extensively used in atomic and nuclear physics is used as the trial wave function for obtaining the $Q\bar{Q}$ mass spectrum.

$$\psi_{nlm}(r,\theta,\phi) = N\left(\frac{r}{b}\right)^l L_n^{l+1/2}\left(\frac{r}{b}\right) exp\left(-\frac{r^2}{2b^2}\right) Y_{lm}(\theta,\phi)$$

where $|N|$ is the normalizing constant given by

$$|N|^2 = \frac{2\alpha^3 n!}{\sqrt{\pi}} \frac{2^{(2(n+l)+1)}}{(2n+2l+1)!}(n+l)! \quad (3)$$

and $L_n^{l+1/2}(x)$ are the associated Laguerre polynomials.

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Results and Discussions

In this model of nonrelativistic dynamics, instanton induced potential and Coulomb like OGEP plays superior role. The instanton effects on masses of orbitally excited state of bottomonia are listed in the table 1.

Table 2 Comparison of Mass Spectra of Bc Mesons

The Mass (Instanton)MeV	The Mass (OGEP) MeV
6531	6533
6397	6400
6337	6345
6302	6317
6279	6301
6267	6290
6261	6284

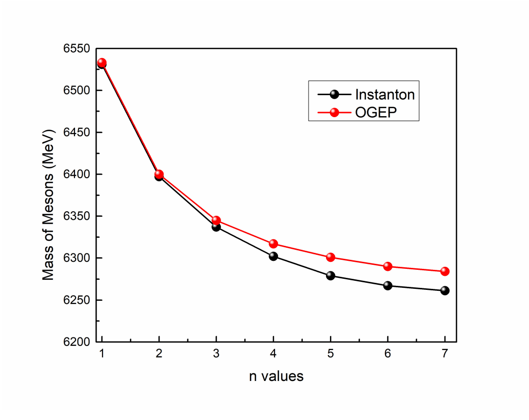

FIG. 1: Ground state masses (in MeV) of B_c mesons in Instanton and OGEP Model

The graph (fig 1) gives the variation of mass with different n values, for B_c and B_c^* mesons. For higher n values the variation of mass is almost negligible. The main objective of this work is to study the variation of ground state B_c meson masses for various n values within the framework of NRQM formalism. There are five parameters in our model. Instantons were introduced in relation to the UA(1) problem and their role was pointed out by t'Hooft by deriving effective interactions by coupling of the instantons and light quarks, whose strength of interaction depends on the instanton density, which was estimated from the gluon condensate of the QCD vacuum. It was argued that the NRQM should include the instanton potential as a short-range non-perturbative gluon effect. Also, lattice QCD suggests that the QCD vacuum contains instantons and its density is consistent with the gluon condensate expected from QCD sum rules. Also, it is well known that chiral symmetry is dynamically broken by the instanton vacuum and massless quarks are transformed into constituent quarks, which acquire mass as a func tion of momentum. Hence a constituent quark model Hamiltonian should have both OGEP and instanton potential. The results showed that the instanton-induced potentials contribute significantly to the mass spectrum of heavy quark mesons.

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