Light D wave meson spectrum and the role of anti-symmetric spin-orbit potential of III in a non - relativistic quark model with instanton induced interaction

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Introduction

The non-relativistic quark models (NRQM) are a class of phenomenological models developed to explain the hadron interactions. They give the most complete description of hadron properties and are the most successful phenomenological models of hadron structure [1-2]. In the constituent quark model, conventional mesons are bound states of a spin ½ quark and spin ½ antiquark bound by a phenomenological potential. The Hamiltonian of these quark models usually contains three main ingredients: the kinetic energy, the confinement potential and a hyperfine interaction term, which has often been taken as an effective one-gluon-exchange potential (OGEP) [3] and the instanton-induced quark-antiquark interaction (III)[4]. In this work we also have investigated the role of the anti-symmetric spin orbit potential derived from instanton induced interaction and its role in the D wave meson K sector

Results and discussions

In our calculation we have expressed the product of quark-antiquark oscillator wave functions in terms of oscillator wave functions corresponding to the relative and centre-of-mass coordinates (CM). The oscillator quantum number for the CM wave functions is restricted to N_{cm}= 0. The Hilbert space of relative wave functions is truncated at radial quantum number n_{max} = 4. The Hamiltonian matrix is constructed for each meson separately in the basis states of $\left| N_{CM} = 0, L_{CM} = 0; \, ^{2S+1}L_J \right\rangle$ and is diagonalised**.** The masses of the singlet and triplet D wave mesons after diagonalisation in harmonic oscillator basis with n_{max}= 4 are listed in table 2. The results show that III along with OGEP interaction is necessary to obtain the meson mass spectra. If OGEP is taken as the only source of hyperfine interaction, the value of α_s necessary to reproduce the hadrons spectrum is generally much larger than one; this leads to a large spin-orbit interaction, which destroys the overall fit to the spectrum. The important role played by III in obtaining the masses of these mesons can be understood by examining table 3. In table 3, we have listed the calculated masses of triplet D wave mesons without the inclusion of III potential. The role of III is crucial in explaining the mass differences of D wave K mesons. We have investigated two singlet light D wave mesons and six triplet light D wave mesons namely [5]. In case of singlet mesons, both CE and CM parts of OGEP are attractive. However, the dominant contribution to the masses comes from the kinetic energy and linear confinement potential. In case of triplet D wave mesons the contribution of III potential is very significant. We note that the dominant contribution to the masses of 1^3D_1 arise from the tensor term of III which is attractive. We note that in case of 1^3D_1 mesons along with the tensor contribution of III, the spin orbit contribution of III is also significant and attractive. The contribution of tensor term of III in case of 1^3D_2 is repulsive. It is to be noted that the anti-symmetric spin orbit potential of the III contributes substantially to the mass difference between the 1^1D_2 and 1^3D_2 mesons in the K meson sector. It should be noted that $K_2(1770)$ receives contribution only from the central part of OGEP, where as $K_2(1820)$ receives additional contribution from the tensor and spin-orbit part of OGEP and III. Table 1 gives the masses of the $K_2(1770)$ and $K_2(1820)$ without the anti-symmetric spin-orbit III after diagonalsing the 5x5 hamiltonian matrix. The mass difference between K*(1680) and $K_2(1820)$ mesons is due to the large difference in tensor part of III potential which in case of the former is attractive and in the latter case is repulsive. In case of ω_3 (1670) and K*(1780) mesons III contribution is repulsive, whereas in case of ϕ_3 (1850) it is attractive.

Conclusions

We have investigated the effect of the III on the masses of the D wave mesons in the frame work of NRQM. We have shown that the computation of the mesonic masses using only OGEP is inadequate. The contribution from the tensor and spin-orbit part of the III is found to be significant in case of triplet D wave mesons. To obtain the physical masses of the mesons in the K sector it is necessary to include the anti-symmetric part of III. There is a good agreement between the calculated and experimental masses of D wave mesons with the inclusion of III.

Table 1. The masses of K- mesons without anti-symmetric spin-orbit III contribution (in MeV)

Meson	Exptl. Mass	Calculated Mass without $V_{III}^{L\Delta}$
$K_2(1770)$	1773±8	1765.8
$K_2(1820)$	1816±13	1966.52

Table 2. Masses of the singlet and triplet mesons (in MeV)

$N^{2S+1}L_J$	Meson	Exptl. Mass	Calculated Mass
1^1D_2	π_2 (1670)	1670±20	1696.6
	K_2 (1770)	1773±8	1727.4
1^3D_1	ω(1650)	1649±24	1649.8
	K*(1680)	1717±27	1720.2
1^3D_2	K_2(1820)	1816±13	1817.2
1^3D_3	ω_3 (1670)	1667 ± 4	1667.1
	K*(1780)	1776 ± 7	1778.9
	ϕ_3 (1850)	1854 ± 7	1855.3

Table 3. Masses of triplet mesons (in MeV) without III

Meson	Exptl. Mass	Calculated Mass
ω(1650)	1649 ± 24	1679.9
K*(1680)	1717 ± 27	1716.1
K_2(1820)	1816 ±13	1730.1
ω_3 (1670)	1667 ± 4	1737.4
K*(1780)	1776 ± 7	1755.9
ϕ_3 (1850)	1854 ± 7	1777.7

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