Calculation of Mass Splittings in D and D_s meson systems in a Non Relativistic Quark Model with OGEP

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Introduction

The complete spectrum of D and D_s states are obtained in a phenomenological NRQM, which consists of a confinement potential and OGEP as effective quark-antiquark potential. In the existing quark models, the OGEP has its origin in the exchange of a single gluon which belongs to an octet representation of the $SU(3)_c$. The OGEP is obtained from the QCD Lagrangian in the non-relativistic limit by retaining terms to the order of $1/c^2$. The effective short-range force stems from the one gluon exchange mechanism. The exchange of gluons can provide a binding between quarks in a hadron. The Hamiltonian employed in our model includes kinetic energy (K), confinement potential and OGEP.

Hyperfine and fine splittings

The hyperfine mass splitting calculated in our model is in good agreement with both experimental data collected in PDG. The EFTs have predicted a hyperfine mass splitting which is lower than the experimental value. The calculated splitting and the comparison with the results of various models is listed in table **??**. The calculations of hyperfine splitting for S-wave has been done by using the formula, $\Delta_{hf}M(nS) = M(n^3S_1) - M(n^1S_0)$; meanwhile spin-orbit splitting for P-wave states are computed by: $\Delta M(nP) = M(n^3P_2) - M(n^3P_1)$ and $\Delta M(nP) = M(n^3P_1) - M(n^3P_0)$.

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Spin-dependent splittings

The eigenvalues of the nonrelativistic Hamiltonian with phenomenological potential should be interpreted as the masses of the centres of gravity of the meson states. The spin-dependent correction to the nonrelativistic Hamiltonian, is responsible for the hyperfine splitting of the mass levels.

TABLE I: **Comparison of Center of Mass of D meson in MeV**

M_{CW}	This Work	[1]	[2]	[3]	Exp.
$1\bar{S}$	1973	1974	1979	1975	1973.92
$2\bar{S}$	2616	2584	2628	2619	2591.37
$3\bar{S}$	3101	3132	3104	3087	
$4\bar{S}$	3475	3650	3510	3474	
$1^3\bar{P}_J$	2446	2430	2453	2457	2434.66
$1\bar{P}$	2440	2414	2448	2449	2431.22
$2^3\bar{P}_J$	3016	2917	2952	3004	
$2\bar{P}$	2976	2905	2949	2986	

The spin averaged masses are defined by,

$$M(n\bar{S}) = \frac{3M(n^3S_1) + M(n^1S_0)}{4} \quad (1)$$

$$M(n\bar{P}) = \frac{3M(n^1P_1) + 5M(n^3P_2) + 3M(n^3P_1) + M(n^3P_0)}{12} \quad (2)$$

with n=1,2,3,... the radial quantum numbers.

The corresponding spin averaged mass and spin dependent splittings are estimated.

The correctness of theoretical description of the fine splitting structure in mesons can be verified by considering the hyperfine splitting in P-state.

It has been found that the measured masses of 1^1P_1 and 2^1P_1 states of mesons practically coincide with the masses of spin-averaged

TABLE II: **Comparison of Center of Mass of the D_s meson in MeV**

M_CW	This work	[4]	[5]	Exp.
$1\bar{S}$	2076	2077.5		
$2\bar{S}$	2710	2696.7	2720.2	2690.6
$3\bar{S}$	3224	3248.4	3236.2	
$4\bar{S}$	3668	3769.2	3664.7	
$1^3\bar{P}_J$	2532	2535.9	2552.4	2531.4
$1\bar{P}$	2514	2510.8	2557.8	2513.4
$2^3\bar{P}_J$	3139	3029.0	3107.2	
$2\bar{P}$	3110	3011.5	3118.9	

TABLE III: **Mass splitting of D meson in MeV.**

Splitting	Our work	[1]	[2]	Exp.
$1^3S_1 - 1^1S_0$	147	143.53	153	140.65±0.1
$2^3S_1 - 2^1S_0$	74	84.14	41	
$3^3S_1 - 3^1S_0$	44	61.58	23	
$4^3S_1 - 4^1S_0$	38	49.72	16	
$D_0(2400)$-$1\bar{S}$	427	340.60	372.25	347.0±29
$D_1(2420)$-$1\bar{S}$	447	393.30	454.25	451.6±0.6
$D_1(2430)$-$1\bar{S}$	457	430.30	474.25	456.0±40
$D_2(2460)$-$1\bar{S}$	487	493.58	493.25	491.4±1.0

triplet P-state:

$$\langle M(n^3P_J)\rangle = \frac{5M(1^3P_2) + 3M(1^3P_1) + M(1^3P_0)}{9} \quad (3)$$

Practically this is the measure of centroid of the three spin-orbit split states, $^3P_0$, $^3P_1$ and $^3P_2$. The correctness is computed by considering $\Delta_{hf}(\langle M(1^3P_J)\rangle - M(n^1P_1))$, where,

TABLE IV: **Mass splitting of D_s meson in MeV.**

Splitting	This work	[4]	[5]	Experiment
$1^3S_1 - 1^1S_0$	144	145.6	143	143.8±0.4
$2^3S_1 - 2^1S_0$	35	84.3	43	
$3^3S_1 - 3^1S_0$	32	61.4	23	
$4^3S_1 - 4^1S_0$	34	49.5	17	
$D_s0(2317)$-$1\bar{S}$	241	271.5	433.5	241.5±0.8
$D_s1(2460)$-$1\bar{S}$	384	358.1	498.5	383.2±0.8
$D_s1(2536)$-$1\bar{S}$	460	439.4	460.5	459.0±0.5
$D_s2(2573)$-$1\bar{S}$	497	507.2	495.5	496.3±1.0
2^1S_0-$1\bar{S}$	608	556.0	612.5	
2^3S_1-$1\bar{S}$	643	640.3	655.5	632.7^{+9}_{-6}

spin-averaged triplet P-state is estimated to be $\langle M(1^3P_J)\rangle = 2532MeV$ and $\langle M(2^3P_J)\rangle = 3139MeV$.

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