S-wave mass spectrum of exotic mesons

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Introduction

The parameters associated with newly discovered mesons such as X(3872) [1] and others,[2, 3] defied every conventional and well known theoretical techniques which were vey successful in predicting and there by undestanding the properties of the system. These included parameters such as mass and decay width. Consequent discoveries by various other groups tended to confirm the same inefficiency of the conventional methods to predict the masses of these newly discovered states . Since then there have been many such discoveries which challenge the conventional quark model (QM). Such mesons which are nonconventional (whose properties can't be explained on the basis of QM) mesons are called "Exotic Mesons" [4].

In the present study we have assumed that the exotic systems are meson molecules to arrive at the masses of XYZ exotic mesons.While intending to treat the exotic system like a meson molecule, we have used non relativistic quark model (NRQM) formalism.

Theoretical Background

A. The Hamiltonian

The typical Hamiltonian of a NRQM is of the form

$$H = K + V_{int} + V_{conf} - K_{CM}$$

where, K is the kinetic energy and V is the potential energy contribution (the confinement potential and the interaction potential energy terms).K_{CM} is kinetic energy of the centre of mass

$$K = M + \frac{p^2}{2\mu} \tag{1}$$

We have assumed confinement potential to be Yukawa potential [5] due to its similarity with nucleon-nucleon interaction, which is of the form

$$V_Y(\vec{r}) = -m_0 \frac{\exp(-rm)}{r} \tag{2}$$

Thus, the full Hamiltonian of the model becomes

$$H = 2K + V_Y + 2V_{conf} + V_{SD} - K_{CM}$$

.

The pivotal equation responsible for calculating the total energy or mass of mesons is given by

$$H|\psi\rangle = E|\psi\rangle \tag{3}$$

TABLE I: Masses of S-wave exotic XYZ states in MeV

$n\ ^{2S+1}L_J$ ($c\bar{d}$-$\bar{c}$d)	Calculated mass	J^{PC}	Exp.mass [3]	Name [3]
$1\ ^1S_0$	3872.28	0^{-+}		
$1\ ^3S_1$	3872.86	1^{--}		
$1\ ^5S_2$	3874.02	2^{-+}		
$2\ ^1S_0$	4014.81	0^{-+}		
$2\ ^3S_1$	4014.3	1^{--}	4008± 1.9	Y(4008)
$2\ ^5S_2$	4016.2	2^{-+}	4024.1± 1.9	$Z_c(4020)$
$3\ ^1S_0$	4124.28	0^{-+}		
$3\ ^3S_1$	4124.7	1^{--}		
$3\ ^5S_2$	4125.54	2^{-+}		
$4\ ^1S_0$	4128.85	0^{-+}		
$4\ ^3S_1$	4129.22	1^{--}	4251±9	X(4260)
$4\ ^5S_2$	4129.97	2^{-+}		
$5\ ^1S_0$	4034.54	0^{-+}		
$5\ ^3S_1$	4034.87	1^{--}		
$5\ ^5S_2$	4035.55	2^{-+}		

The computation of meson masses and their excited states is done by evaluating the matrix

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elements. The energy eigen value calculation of the Hamiltonian is done in the harmonic oscillator basis.

Results and Conclusion

The study,using the meson molecular theoretical framework, calculates the S-wave and their radially excited states .The results are shown in table 1. Our calculations show that some of the experimentally confirmed states of exotic mesons (X,Y,Z) could be the radially excited states of a fundamental molecular state. Some of the theoretically found masses are in very good agreement with the experimentally observed masses. The theoretical predictions shown above not only estimate the masses of a wealth of states but also points at the possibility of many X,Y and Z states being the excited states of a $c\bar{d}$ - $\bar{c}$d system. The investigation also helps us to ascertain partially determined parameter such as J^{PC} and will serve as a limit to confine the mass values.

References

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