Magnetic properties of $D^*(2007)^0$ and $D^*(2010)^\pm$ meson in the constitute quark model

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Introduction

The spectrum of charmed mesons is now well established in ground states as well as many of new excited states are available, particularly the S−wave states, namely $D^*(2007)^0$ and $D^*(2010)^\pm$ are both measured with a quantum number $J^P = 1^-$ [1] (see in Table I). Phenomenology study, based on potential models predict the numerous new orbitally and radially excited states of charmed mesons; such a states are also identified with their Regge trajectories [2]. Which lead us to study of their various properties like; decay constants, leptonic and semi-leptonic decays [3, 4], magnetic moments, magnetic dipole transitions and the radiative decays [5, 6].

The magnetic moments of the particles is purely the function of its structural parameters so that it serves an important role in the study of their internal dynamics. The radiative decay based on electromagnetic transitions can also probe the charge structure of hadrons and is useful tool for the determination of their quantum numbers. The radiative decay is done by an exchange of massless photon among the participating hadrons without contained phase space restriction.

In this paper, we study the magnetic moments, magnetic dipole transitions and the radiative decay of $D^*(2007)^0$ and $D^*(2010)^\pm$ in a non-relativistic constitute quark model using the spin-flavour wave functions of the constituting quarks and their effective masses.

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TABLE I: Masses of the charmed mesons using in this work (in MeV).

State	J^P	Meson	[2]	PDG[1]
1^3S_0	0^-	D^0	1884	1864.83±0.05
		$D^\pm$		1869.58±0.09
1^3S_1	1^-	$D^*(2007)^0$	2010	2006.85±0.05
		$D^*(2010)^\pm$		2010.26±0.05

Magnetic moments

The magnetic moment of the particular meson (μ_M) can be expressed in the form of expectation value

$$\mu_M = \sum_q \left\langle \Phi_{sf} \middle| \mu_{q_z} \middle| \Phi_{sf} \right\rangle ; q = u, d, s, c. \quad (1)$$

with a magnetic moment of the individual quark

$$\mu_q = Q \frac{e}{2m_q^{eff}} \sigma_q \quad (2)$$

where Φ_{sf} represents the spin-flavour wave function of a participating meson, Q is charge and σ_q is the spin of the constitute quark, and the effective mass of each constituting quark (m_q^{eff}) can be defined in terms of the constituting quark mass (m_q)[7, 8].

An obtained expressions of magnetic moments for D^{*0} and $D^{*\pm}$ meson are listed in the second column of Table II and the calculated results are presented in third column using the meson masses from V. Kher et al. [2] (see in Table II); in the unit of nuclear magnetons $\left(\mu_N = \frac{e\hbar}{2m_p}\right)$. In the present study, we fitted the constitute quark masses; $m_{\bar{u}/\bar{d}} = 460$ MeV and $m_c = 1400$ MeV [2].

TABLE II: Magnetic moments of $D^*(2007)^0$ and $D^*(2010)^{\pm}$ meson (in μ_N).

Meson	Magnetic moment	Present	[5]
D^{*0}	$\frac{2}{3}\mu_c - \frac{2}{3}\mu_{\bar{u}}$	−0.845	−1.21
$D^{*\pm}$	$\frac{2}{3}\mu_c + \frac{2}{3}\mu_{\bar{d}}$	1.042	1.06

TABLE III: Magnetic dipole (M1) transitions of $D^*(2007)^0$ and $D^*(2010)^{\pm}$ meson (in μ_N).

Meson	M1 transition	Present	[5]
$D^{*0} \to D^0$	$\frac{2}{3}\mu_c + \frac{2}{3}\mu_{\bar{u}}$	1.671	1.68
$D^{*\pm} \to D^+$	$\frac{2}{3}\mu_c - \frac{1}{3}\mu_{\bar{d}}$	−0.216	−0.40

Magnetic dipole transitions and Radiative decays

Magnetic dipole (say M1) transitions lead a transition from vector (spin=1) to pseudoscalar (spin=0) mesons, without changing the relative orbital momentum of the quark-antiquark pair. It is necessary for the study of radiative decays $M_{\mathcal{V}} \to M_{\mathcal{P}} + \gamma$, where $M_{\mathcal{V}}$ and $M_{\mathcal{P}}$ are initial and final state vector and pseudoscalar meson; respectively. Using an Eqn.(2) between an appropriate spin-flavour wave functions of pseudoscalar and vector mesons. An obtained expressions of magnetic dipole transitions ($\mu_{M_{\mathcal{V}} \to M_{\mathcal{P}}}$) for D^{*0} and $D^{*\pm}$ are listed in the second column of Table III.

For the M1 transitions, the decay width of the vector mesons can be written in terms of photon momentum (k) and proton mass (m_p) as

$$\Gamma_{M_{\mathcal{V}} \to M_{\mathcal{P}} + \gamma} = \frac{4\alpha k^3}{3m_p} \frac{2}{2J+1} (\mu_{M_{\mathcal{V}} \to M_{\mathcal{P}}})^2 \quad (3)$$

where J is the total angular momentum of the vector meson and $\alpha \sim \frac{1}{137}$ is the fine structure constant for the electromagnetic transitions [5, 6].

Results and Discussion

We try to use constitute quark model to describe the magnetic properties of the ground state S−wave charmed mesons. Our calculated magnetic moments, magnetic dipole transitions and the radiative M1 decay widths of $D^*(2007)^0$ and $D^*(2010)^{\pm}$ meson are presented in Table II - III and IV respectively. In order to test model we have compared our predictions with the results obtained in the bag model frame work Ref.[5]. Our results of magnetic moments, magnetic dipole transitions and M1 radiative decay are in well aggrement with Ref.[5] except the decay rate of D^{*0} is overestimated. The future experiment $\overline{\mathsf{P}}\mathsf{ANDA}$ [9] will expected to give a precise observation of radiative decay in low energy regime Quantum Chromodynamics (QCD).

TABLE IV: Radiative decay widths of $D^*(2007)^0$ and $D^*(2010)^{\pm}$ meson (in keV).

Radiative decay	Present	[5]
$D^{*0} \to D^0 + \gamma$	37.45	19.7
$D^{*+} \to D^+ + \gamma$	0.852	1.10

We would like to extend our work in the light and others ground state heavy mesons.

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