A confining quark model suggestion against Ds*(2317) and Ds*(2460) as chiral partners of standard Ds

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5º E N Física Hadrónica, 2006 Porto

A confining quark model suggestion against Ds*(2317) and Ds*(2460) as chiral partners of standard Ds

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1. The chiral conjecture for the Ds*(2317)
2. A simple confining model
3. Chiral partners in the D and Ds families
4. Conclusion

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In this talk it is shown that chiral symmetry does not add new states to the standard meson spectrum. This is exemplified with the simplest confining and chiral invariant quark-antiquark interaction.

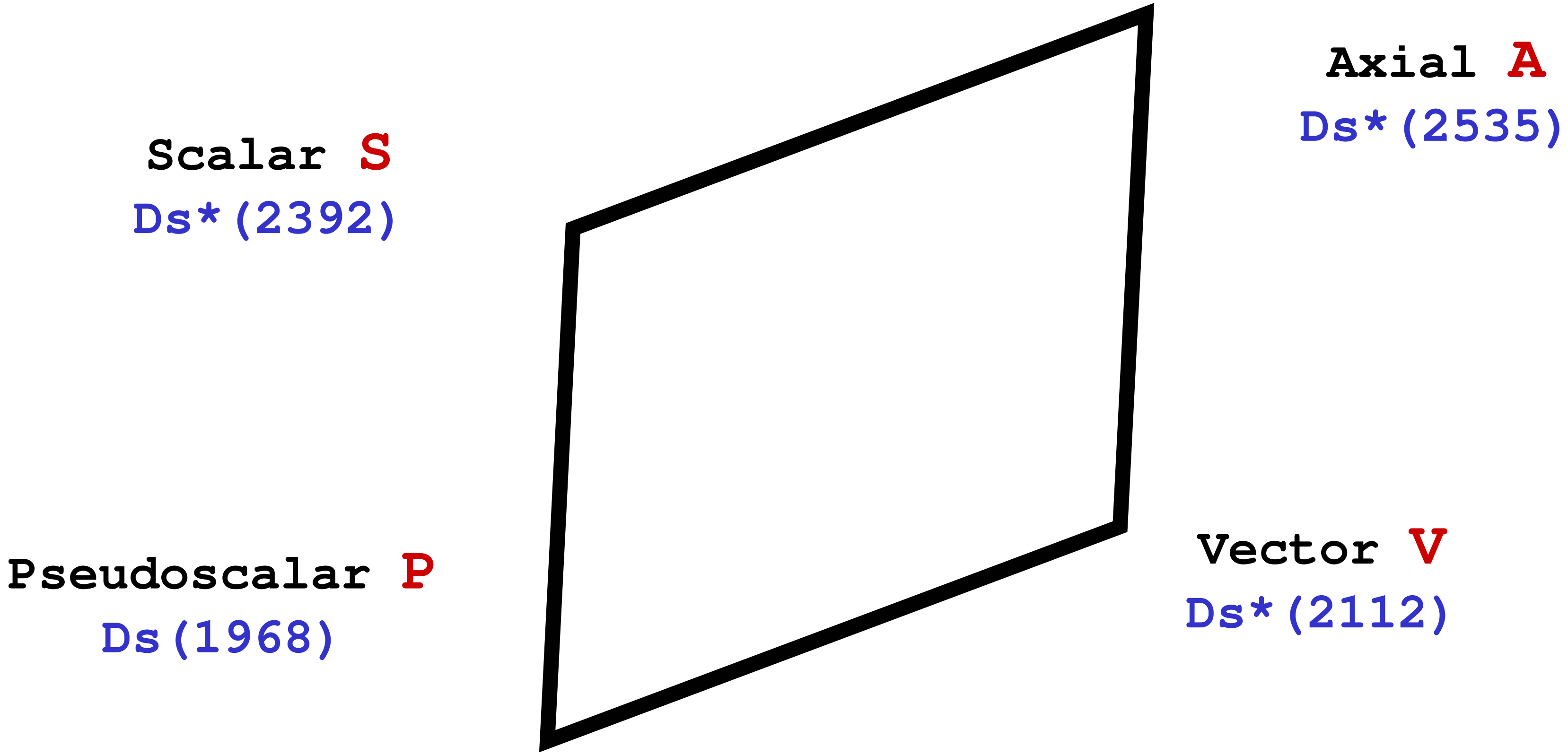
Although the model used here remains to be calibrated, this suggests that the challenging recently observed at BABAR, CLEO and BELLE, Ds*(2317) and Ds*(2460) mesons might not fit as global chirally rotated quark-antiquark Ds mesons.

1. The chiral conjecture for the Ds*(1317)

The new Ds*(1317) does not fit as a standard quark model qq state.

Neither the quark model nor lattice QCD are able to describe the Ds*(2317) and Ds*(2460) as standard quark-antiquark mesons. The new Ds* do not fit in the spectrum of standard quark-antiquark mesons, which is governed by the quark constituent masses and by a confining potential, together with well known hyperfine, spin-orbit and tensor potentials , see Table 1.

Quenched lattice QCD, which only accesses the quark-antiquark spectrum, confirms that these Ds* masses are too light for standard $q\bar{q}$ mesons.



The Ds puzzle revived the conjecture of chiral partnership by Nowak, Rho & Zahed and by Bardeen & Hill

2. A simple confining model

The hamiltonian can be approximately derived from QCD, up to the first cumulant order, of two gluons, which can be evaluated in the modified coordinate gauge,

$$H = \int d^3x \left[\psi^\dagger(x)\, (m_0\beta - i\vec{\alpha}\cdot\vec{\nabla})\, \psi(x) \; + \frac{1}{2} g^2 \int d^4y \right.$$

$$\left. \overline{\psi}(x)\gamma^\mu \frac{\lambda^a}{2}\psi(x)\langle A_\mu^a(x)A_\nu^b(y)\rangle\, \overline{\psi}(y)\gamma^\nu \frac{\lambda^b}{2}\psi(y) \; + \; \cdots \right.$$

$$g^2\langle A_\mu^a(x)A_\nu^b(y)\rangle \simeq -\frac{3}{4}\delta_{ab}g_{\mu 0}g_{\nu 0}\left[K_0^3(\mathbf{x}-\mathbf{y})^2 - U\right]$$

TABLE I: Matrix elements of the spin-dependent potentials

$^{2S+1}L_J$	spin-indep.	spin-spin	spin-orbit	tensor
$^1S_0$	1	-3/4	0	0
$^3P_0$	1	1/4	-2	-1/3
$^3S_1$	1	1/4	0	0
$^3D_1$	1	1/4	-3	-1/6
$^3S_1 \leftrightarrow ^3D_1$	0	0	0	$\sqrt{2}/6$
$^3P_1$	1	1/4	-1	1/6
$^1P_1$	1	-3/4	0	0

I get the $J^P = 0^-$, ${}^1S_0$ pseudoscalar (P) equations,

$$\left\{ \left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{1 - S_q S_{\bar q}}{k^2} \right) \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} + \left(\frac{\varphi'_q \varphi'_{\bar q}}{2} + \frac{C_q C_{\bar q}}{k^2} \right) \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} - M \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \right\} \begin{pmatrix} \nu^+_{{}^1S_0}(k) \\ \nu^-_{{}^1S_0}(k) \end{pmatrix} = 0 \, , \tag{1}$$

the $J^P = 0^+$, ${}^3P_0$ scalar (S) equations,

$$\left\{ \left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{1 + S_q S_{\bar q}}{k^2} \right) \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} + \left(\frac{\varphi'_q \varphi'_{\bar q}}{2} - \frac{C_q C_{\bar q}}{k^2} \right) \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} - M \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \right\} \begin{pmatrix} \nu^+_{{}^3P_0}(k) \\ \nu^-_{{}^3P_0}(k) \end{pmatrix} = 0 \, . \tag{2}$$

the $J^P = 1^-$, coupled ${}^3S_1$ and ${}^3D_1$ vector (V and V^*) equations ,

$$\Bigg\{ \left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{7 - 4S_q - 4S_{\bar q} + S_q S_{\bar q}}{3k^2} \right) \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} + \left(-\frac{\varphi'_q \varphi'_{\bar q}}{6} - \frac{C_q C_{\bar q}}{3k^2} \right) \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$+ \left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{8 + 4S_q + 4S_{\bar q} + 2S_q S_{\bar q}}{3k^2} \right) \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} + \left(\frac{\varphi'_q \varphi'_{\bar q}}{6} - \frac{2C_q C_{\bar q}}{3k^2} \right) \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$- \frac{(1 - S_q)(1 - S_{\bar q})}{3k^2} \begin{bmatrix} 0 & 0 & \sqrt{2} & 0 \\ 0 & 0 & 0 & \sqrt{2} \\ \sqrt{2} & 0 & 0 & 0 \\ 0 & \sqrt{2} & 0 & 0 \end{bmatrix} - \left(\frac{\varphi'_q \varphi'_{\bar q}}{3} - \frac{C_q C_{\bar q}}{3k^2} \right) \begin{bmatrix} 0 & 0 & 0 & \sqrt{2} \\ 0 & 0 & \sqrt{2} & 0 \\ 0 & \sqrt{2} & 0 & 0 \\ \sqrt{2} & 0 & 0 & 0 \end{bmatrix} - M \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \Bigg\} \begin{pmatrix} \nu^+_{{}^3S_1}(k) \\ \nu^-_{{}^3S_1}(k) \\ \nu^+_{{}^3D_1}(k) \\ \nu^-_{{}^3D_1}(k) \end{pmatrix} =$$

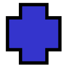
the $J^P = 1^+$, coupled ${}^1P_1$ and ${}^3P_1$ axialvector (A and A^*) equations

$$\Bigg\{ \left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{3 - S_q S_{\bar q}}{k^2} \right) \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} + \left(\frac{\varphi'_q \varphi'_{\bar q}}{2} + \frac{C_q C_{\bar q}}{k^2} \right) \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\left(-\frac{d^2}{dk^2} + E_q(k) + E_{\bar q}(k) + \frac{{\varphi'_q}^2 + {\varphi'_{\bar q}}^2}{4} + \frac{2}{k^2} \right) \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} + \left(-\frac{\varphi'_q \varphi'_{\bar q}}{2} \right) \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$+ \frac{S_q - S_{\bar q}}{k^2} \begin{bmatrix} 0 & 0 & \sqrt{2} & 0 \\ 0 & 0 & 0 & \sqrt{2} \\ \sqrt{2} & 0 & 0 & 0 \\ 0 & \sqrt{2} & 0 & 0 \end{bmatrix} - M \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \Bigg\} \begin{pmatrix} \nu^+_{{}^1P_1}(k) \\ \nu^-_{{}^1P_1}(k) \\ \nu^+_{{}^3P_1}(k) \\ \nu^-_{{}^3P_1}(k) \end{pmatrix} = 0 \, ,$$

3. Chiral Partners in the D and Ds families

To study chiral partners we interpolate
from the false chiral invariant vacuum  to
the true chiral symmetry breaking vacuum 

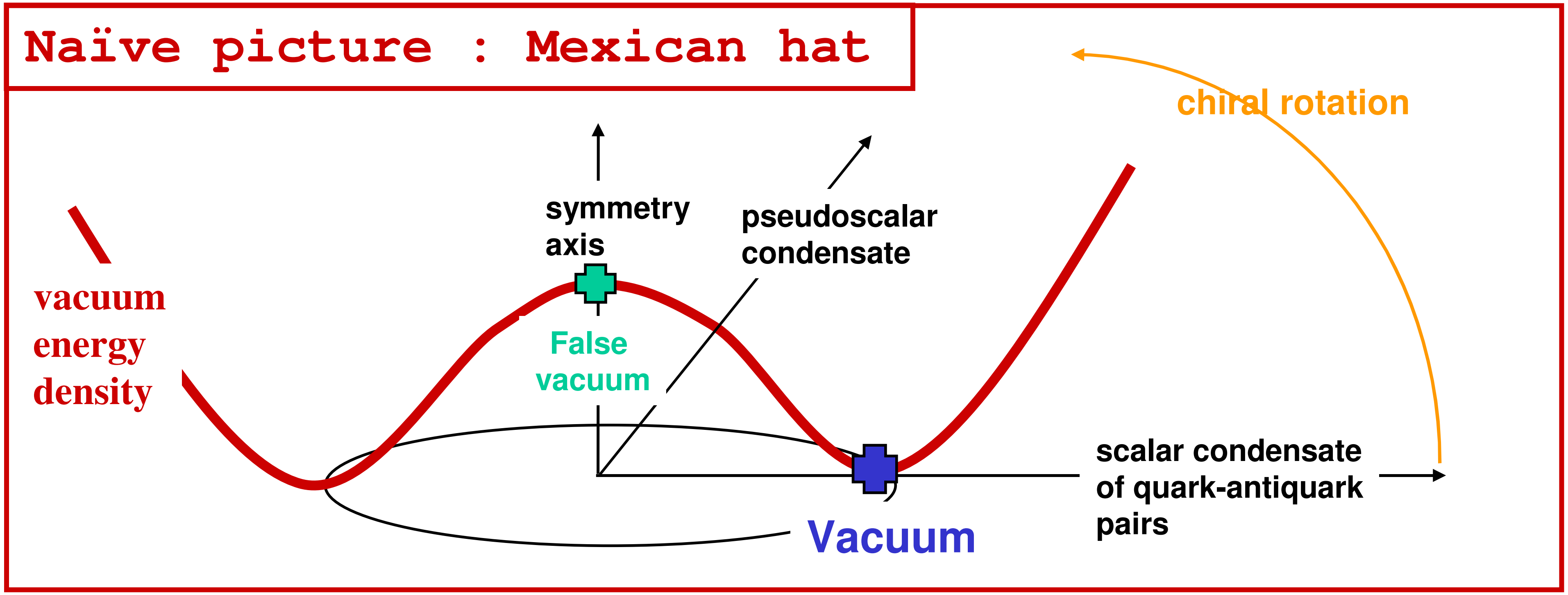
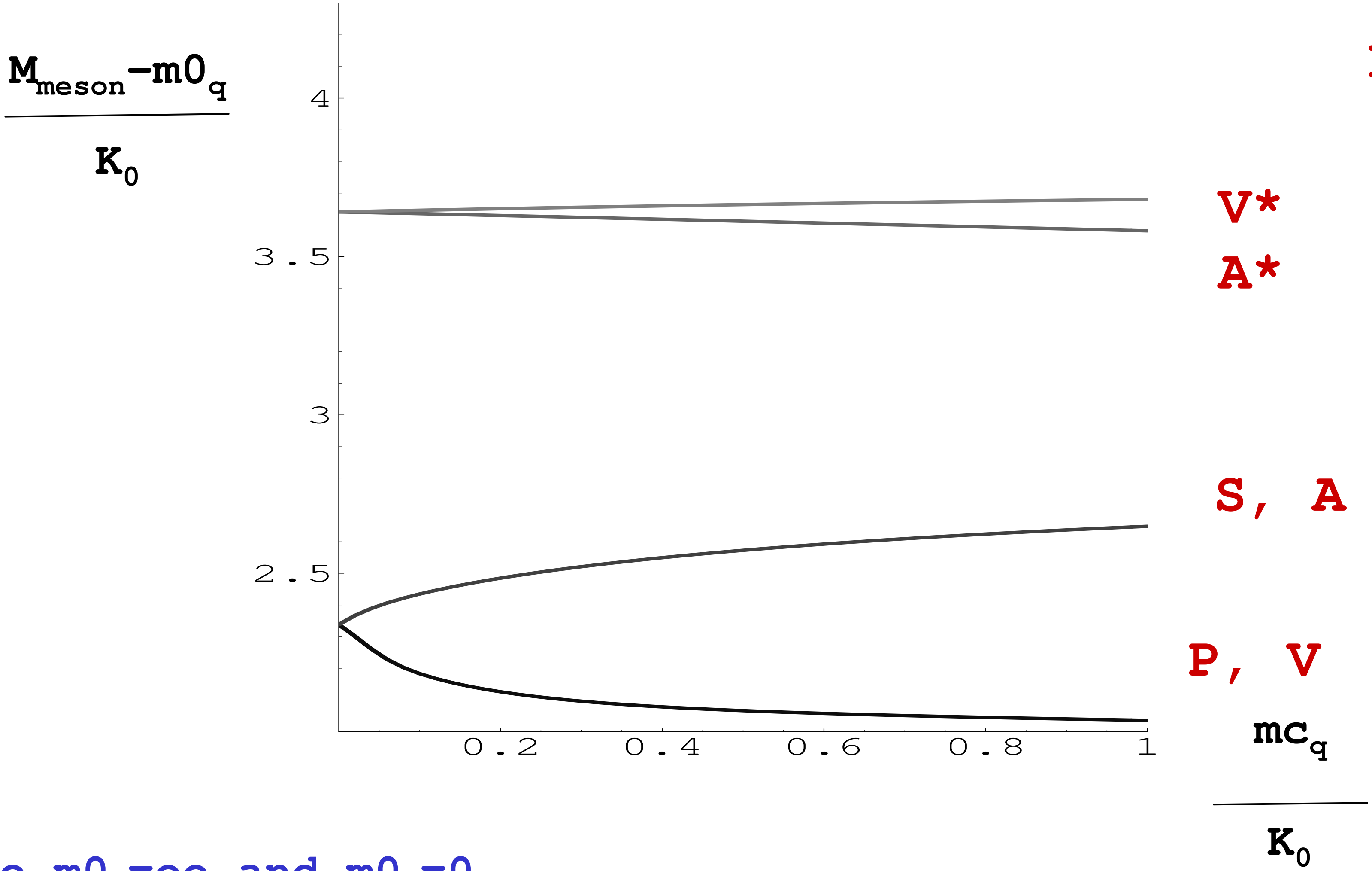


FIG. 1



Here $m0_{\bar q}$=oo and $m0_q$=0.

The light constituent quark mass is interpolated from the zero mass of the chiral invariant false vacuum to the solution mc of the mass gap equation in the true vacuum.

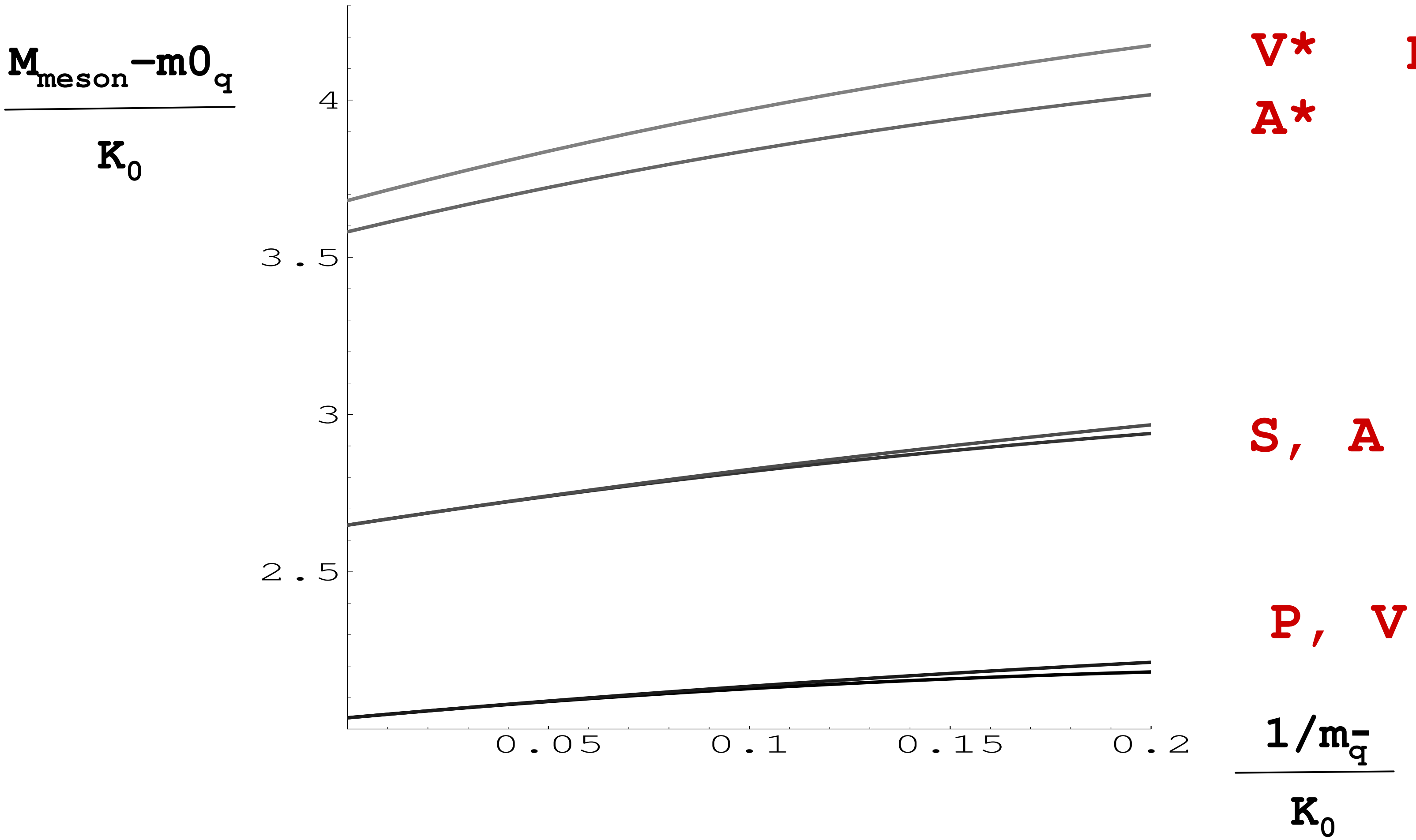


FIG. 2

Here, mq=mc and the current quark mass m0=0 are constant. The heavy antiquark masses decreases from the infinite limit of Isgur-Wise to the actual charm mass.

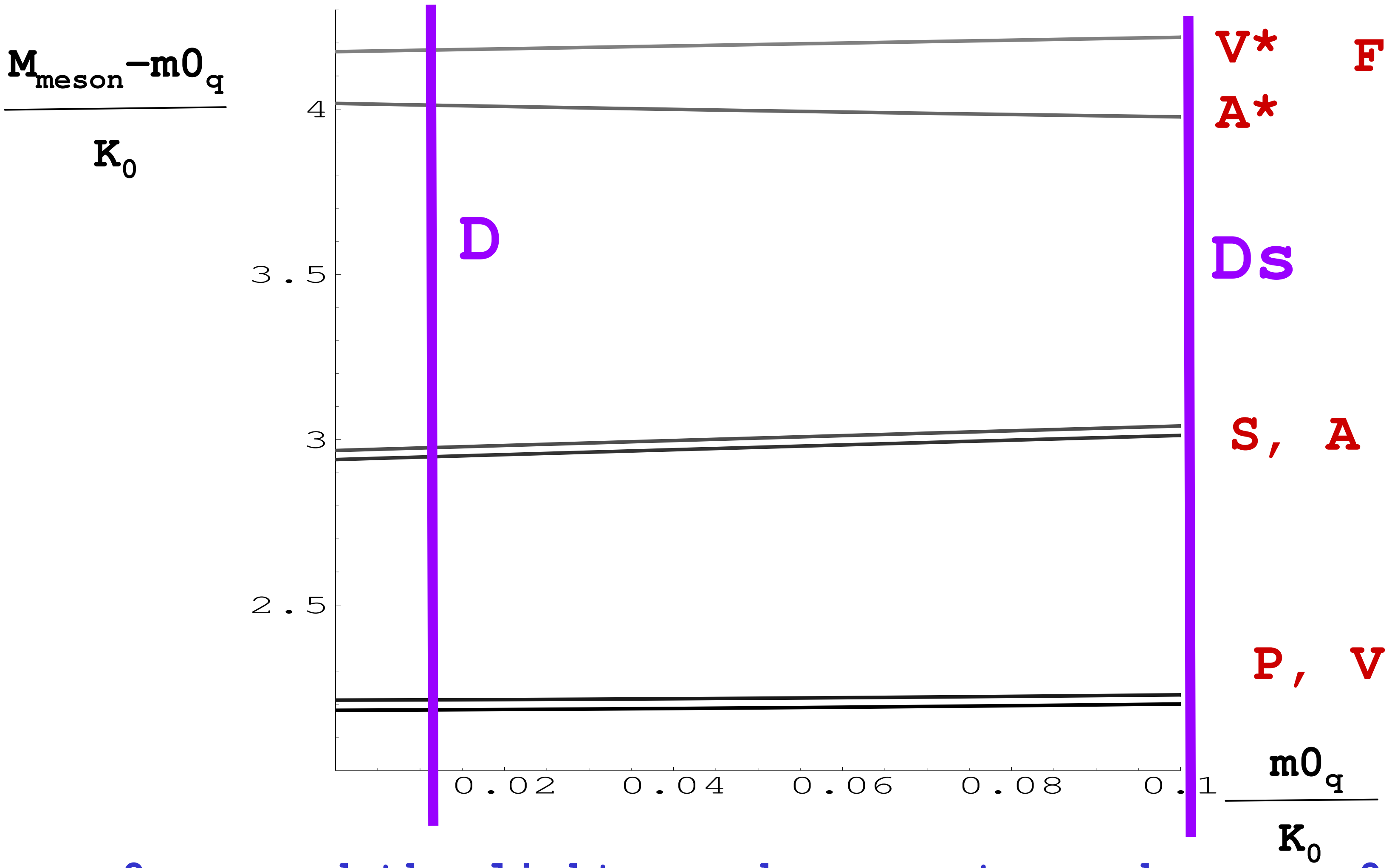
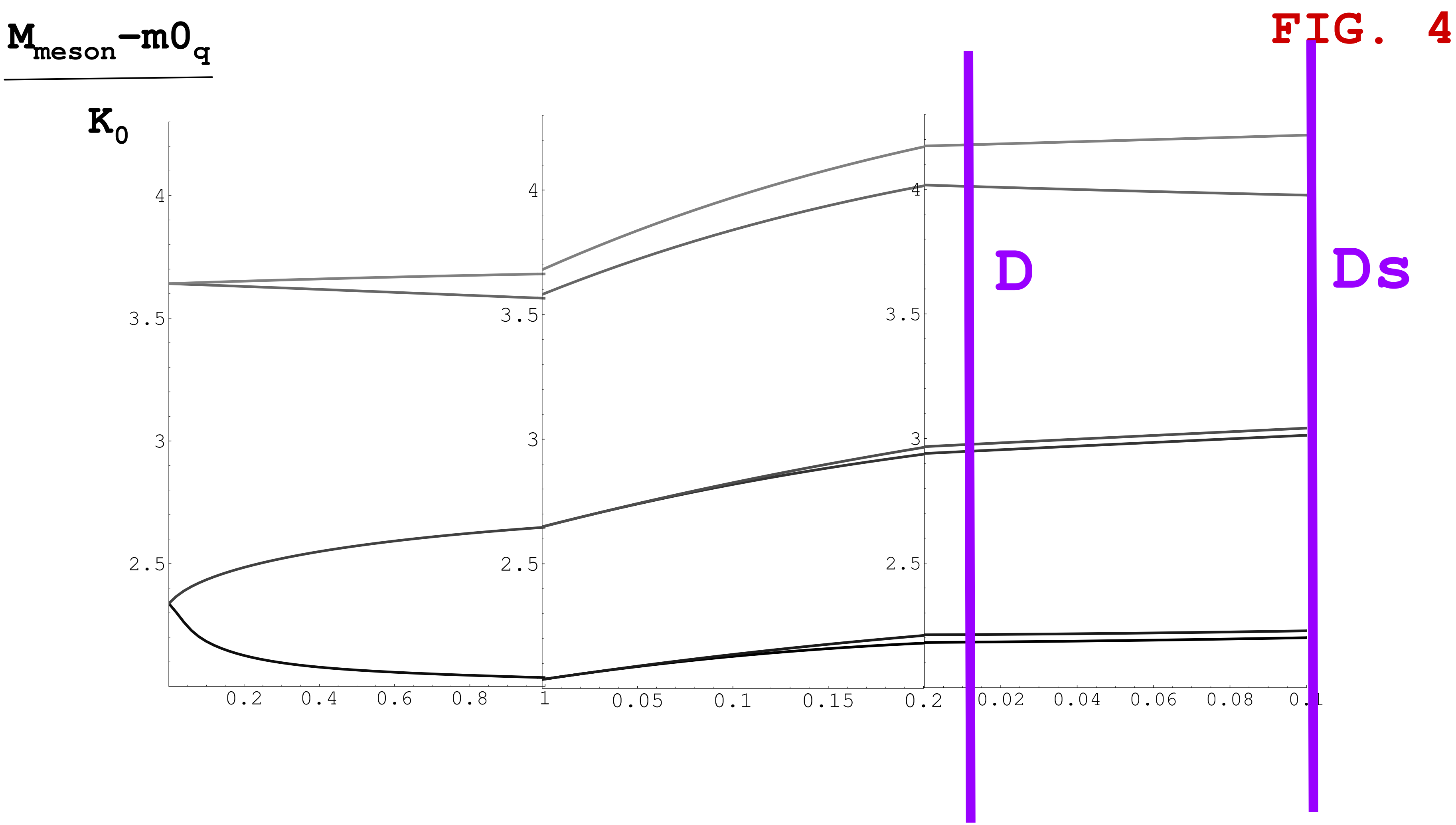


FIG. 3

Here $m0_q$=00 and the light quark current quark mass $m0_q$ interpolates from the vanishing mass of the chiral limit, passes by the **u** and **d** current quark masses and ends up at the **s** quark mass.



Notice that all the figures 1,2 & 3 match, from the chiral invariant vacuum to D and Ds mesons with finite masses

4. Conclusion

Qualitatively, the present results agrees both with the chiral models, and with the quark models.

However, the confining chiral quark models remain to be calibrated. Quantitatively the splittings, in particular the hyperfine splitting, are far from the experimental results.

Nevertheless, assuming that calibration is possible,the similar experimental 410 to 423 MeV mass splittings of the vector D*(2007-2010) and axialvector D(2420), and vector Ds*(2112) and axialvector D_s^*(2535), and the larger lattice splittings all sugest that the chiral partners of the q $\bar{q}$ mesons Ds*(2112) and Ds(1968) are respectively the q $\bar{q}$ axialvector Ds*(2535) and a yet undetected scalar Ds*(2392).

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