Microscopic Model of Charmonium Strong Decays

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Contents

1.- Introduction

1.1.- A rather poorly understood area in hadronic physics

Renew interest of charmonium $\longrightarrow$ discovery of XYZ mesons performed by B factories

One open topic: **strong decays of $c\bar{c}$ states**

Poorly understood area:

- *Is difficult to solve problems within QCD non-perturbative regime*

$\longrightarrow$ *Much of our knowledge of strong interaction comes from strong decays*

- *Open-flavor strong decays are mediated by $q\bar{q}$ pair production.*
- *Several phenomenological models have been developed to deal with this topic*
- *The relation of the phenomenological models to QCD microscopic decay mechanism has not been established*

2.- Modeling strong decays

2.1.- How to deal with it

$^3P_0$ MODEL

- *The $q\bar{q}$ pair is created from the vacuum* $\longrightarrow J^{PC} = 0^{++}$
- *The created $q\bar{q}$ pair together with the $q\bar{q}$ pair in the original meson regroups in the two outgoing mesons via a quark rearrangement process* $\longrightarrow$ *OZI rule*

FLUX-TUBE MODEL

- *Similar to $^3P_0$ model*
- *Takes into account the dynamics of the flux-tubes by including the overlaps of the flux-tube of the initial meson with those of the two outgoing mesons.*

MICROSCOPIC MODEL

- *The strong decays are driven by interquark Hamiltonian which determines the spectrum*

2.- Modeling strong decays

2.2.- Reference works on microscopic decay model

——— Little previous work in this area ———

'Charmonium: The model' and 'Charmonium: Comparison with experiment'
E. Eichten, K. Gottfried, T. Kinoshita, K.D. Lane and T.-M. Yan
Phys. Rev. D **17** *3090 (1978);* **21** *203 (1980)*

$\longrightarrow$ Main features:

- Assume $q\bar{q}$ pair production from the **static vector linear confining interaction**
- The $c\bar{c}$ **wave functions** are those **coming from the model** except for the **open-charm meson wave functions** which are approximated by **gaussians**

$\longrightarrow$ Comments about results:

- Very early theoretical study of $c\bar{c}$ states
- There is an update $\longrightarrow$ Phys. Rev. D **73** 014014 (2006)
- Predicted partial and total widths of $\psi(3770)$, $\psi(4040)$ and $\psi(4160)$

2.- Modeling strong decays

2.2.- Reference works on microscopic decay model (Continuation)

'On the mechanism of open-flavor strong decays'
E.S. Ackleh, T. Barnes and E.S. Swanson
Phys. Rev. D **54**, *6811 (1996)*

→ Main features:

- Assume $q\bar{q}$ pair production from the **scalar linear confining interaction** and **One-Gluon Exchange (OGE)**
- Meson wave functions as **SHO wave functions** → Analytical decay rates

→ Comments about results:

- Overall scale of the total decay amplitudes is too large

The discrepancy may be
- NOT DUE
  - Choice of model parameters
  - Wave function approximation
- POSSIBLY DUE
  - Non-relativistic reduction of amplitudes
  - Assumption of scalar linear potential
  - Disregard a possible constant

'It would be interesting to apply these microscopic decay calculations to charmonium because the transverse OGE should be much smaller'

2.- Modeling strong decays

2.3.- Summary

	E.S. Ackleh *et al.*	E. Eichten *et al.*	J. Segovia *et al.*
Framework	Non-relativistic	Non-relativistic	Non-relativistic
Kernel	Scalar linear + OGE	Static linear	Vector-scalar $\times$ (screened + cte) + OGE
W.F.	SHO	Exact + SHO	Exact solutions
Coupled	No	Yes	No
Phase-Space	Relativistic	Relativistic	Relativistic
Application	Some light meson decays	Open-charm decays of $c\bar{c}$	Open-charm decays of $c\bar{c}$

Very recent works

- *Yu.A. Simonov arXiv:1103.4028v1 [hep-ph] 21 Mar 2011*
- *Bao-Fei Li et al. arXiv:1105.1620v1 [hep-ph] 9 May 2011*

3.- Constituent quark model

3.1.- Main features

- Spontaneous chiral symmetry breaking (Goldstone-Bosons exchange):

$$\mathcal{L} = \bar{\psi}\left(i\gamma^{\mu}\partial_{\mu} - MU^{\gamma_5}\right)\psi \to \quad U^{\gamma_5} = 1 + \frac{i}{f_\pi}\gamma^5\lambda^a\pi^a - \frac{1}{2f_\pi^2}\pi^a\pi^a + \ldots$$

$$M(q^2) = m_q F\left(q^2\right) = m_q\left[\frac{\Lambda^2}{\Lambda^2+q^2}\right]^{1/2}$$

- QCD perturbative effects (One-Gluon Exchange):

$$\mathcal{L} = i\sqrt{4\pi\alpha_s}\,\bar{\psi}\gamma_\mu G^\mu\lambda^c\psi$$

- Confinement:

$$V_{\rm CON} = a_s V_{\rm CON}^{\rm scalar} + (1-a_s)V_{\rm CON}^{\rm vector}$$

$\Rightarrow$ Screened potential:

$$V_{\rm CON}^{C}(\vec{r}_{ij}) = \left[-a_c(1-e^{-\mu_c r_{ij}}) + \Delta\right](\vec{\lambda}_i^c\cdot\vec{\lambda}_j^c)$$

$$\begin{cases} V_{CON}^{C}(\vec{r}_{ij}) = \left(-a_c\mu_c r_{ij} + \Delta\right)(\vec{\lambda}_i^c\cdot\vec{\lambda}_j^c) & r_{ij}\to 0 \\ V_{CON}^{C}(\vec{r}_{ij}) = (-a_c+\Delta)(\vec{\lambda}_i^c\cdot\vec{\lambda}_j^c) & r_{ij}\to\infty \end{cases}$$

3.- Constituent quark model

3.2.- Some recent applications

- **N-N interaction**
  - D.R. Entem, F. Fernández and A. Valcarce, Phys. Rev. C **62**, 034002 (2000)
  - B. Julia-Diaz, J. Haidenbauer, A. Valcarce and F. Fernández, Phys. Rev. C **65**, 034001 (2002)
- **Baryon spectrum**
  - H. Garcilazo, A. Valcarce and F. Fernández, Phys. Rev. C **63**, 035207 (2001)
  - H. Garcilazo, A. Valcarce and F. Fernández, Phys. Rev. C **64**, 058201 (2001)
- **Meson spectrum**
  - J. Vijande, A. Valcarce and F. Fernández, J. Phys. G **31**, 481 (2005)
  - J. Segovia, D.R. Entem and F. Fernández, Phys. Rev. D **78** 114033 (2008)
  - J. Segovia, D.R. Entem and F. Fernández, accepted by Phys. Rev. D
- **Molecular states**
  - P. G. Ortega, J. Segovia, D. R. Entem and F. Fernández, Phys. Rev. D **81**, 054023 (2010)

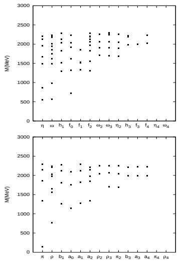
3.- Constituent quark model

3.2.- Some recent applications (Continuation)

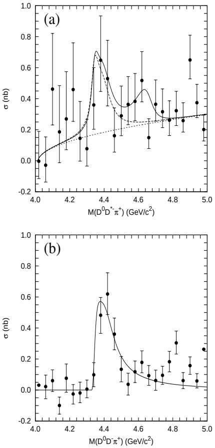
Deuteron

	CQM	NijmII	Bonn B	Exp.
ϵ_d (MeV)	−2.2242	−2.2246	−2.2246	−2.224575
P_D (%)	4.85	5.64	4.99	-
Q_d (fm^2)	0.276	0.271	0.278	0.2859 ± 0.0003
A_S ($\mathrm{fm}^{-1/2}$)	0.891	0.8845	0.8860	0.8846 ± 0.0009
A_D/A_S	0.0257	0.0252	0.0264	0.0256 ± 0.0004

Light mesons



Charmonium reactions



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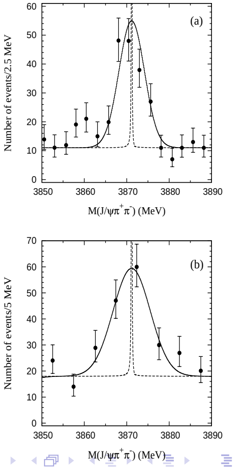
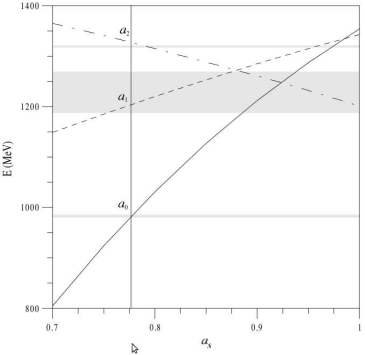


3.- Constituent quark model

3.3.- Model parameters



Quark masses	m_c (MeV)	1763
Confinement	a_c (MeV)	507.4
	μ_c (fm^{-1})	0.576
	Δ (MeV)	184.432
	a_s	0.81
One-gluon exchange	α_0	2.118
	Λ_0 (fm^{-1})	0.113
	μ_0 (MeV)	36.976
	$\hat{r}_0$ (fm)	0.181
	$\hat{r}_g$ (fm)	0.259

J. Vijande et al.
J. Phys. G **31** *481 (2005)*

3.- Constituent quark model.

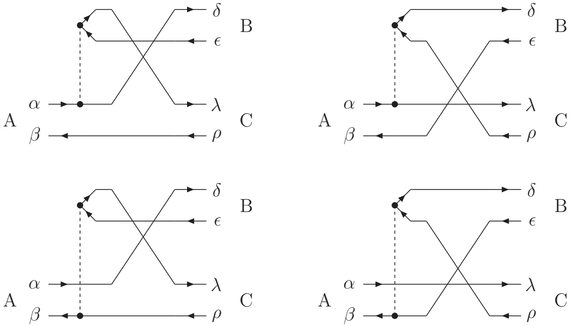
3.4.- Charmonium

(nL)	States	M_{CQM}	M_{EXP}	$\Gamma^{e^+e^-}_{CQM}$	$\Gamma^{e^+e^-}_{EXP}$
(1S)	J/ψ	3096	3096.916 ± 0.011	3.93	5.55 ± 0.14
(2S)	$\psi(2S)$	3703	3686.09 ± 0.04	1.78	2.43 ± 0.05
(1D)	$\psi(3770)$	3796	3772 ± 1.1	0.22	0.22 ± 0.05
	$X(4008)$		4008 ± 40		
(3S)	$\psi(4040)$	4097	4039 ± 1	1.11	0.83 ± 0.20
(2D)	$\psi(4160)$	4153	4153 ± 3	0.30	0.48 ± 0.22
	$X(4260)$		4260 ± 10		
(4S)	$X(4360)$	4389	4361 ± 9	0.78	-
(3D)	$\psi(4415)$	4426	4421 ± 4	0.33	0.35 ± 0.12
(5S)	$X(4630)$	4614	4634^{+8+5}_{-7-8}	0.57	-
(4D)	$X(4660)$	4641	$4664 \pm 11 \pm 5$	0.31	-

J. Segovia, D. R. Entem and F. Fernández, Phys. Rev. D **78**, *114033 (2008)*

4.- Microscopic decay model

4.1.- Contribution diagrams and interaction Hamiltonian



$$H_I = \frac{1}{2}\int d^3x d^3y\, J^a(\vec{x}) K(|\vec{x}-\vec{y}|) J^a(\vec{y})$$

4.- Microscopic decay model

4.2.- Currents and Kernels

- Currents are assumed to be a color octet. When the color dependence $\lambda^a/2$ is factored out they are given by

$$J(\vec{x}) = \bar{\psi}(\vec{x})\Gamma\psi(\vec{x}) = \begin{cases} \bar{\psi}(\vec{x})\mathcal{I}\psi(\vec{x}) & \text{Scalar Lorentz structure} \\ \bar{\psi}(\vec{x})\gamma^0\psi(\vec{x}) & \text{Static term of vector Lorentz structure} \\ \bar{\psi}(\vec{x})\vec{\gamma}\psi(\vec{x}) & \text{Spatial term of vector Lorentz structure} \end{cases}$$

- Kernels

$$K(r) = \begin{cases} -4\left[-a_c(1-e^{-\mu_c r})+\Delta\right] & \text{Scalar confining interaction} \\ +4\left[-a_c(1-e^{-\mu_c r})+\Delta\right] & \text{Static vector confining interaction} \\ -4\left[-a_c(1-e^{-\mu_c r})+\Delta\right] & \text{Transversal vector confining interaction} \\ +\frac{\alpha_s}{r} & \text{Color Coulomb OGE} \\ -\frac{\alpha_s}{r} & \text{Transverse OGE} \end{cases}$$

- Notation

$$\text{JKJ decay model} \Rightarrow \begin{cases} sKs \\ j^0Kj^0 \\ j^TKj^T \end{cases}$$

4.- Microscopic decay model

4.3.- Some Formulas

$$\Gamma_{A\to BC} = 2\pi \frac{E_B E_C}{M_A k_0} \sum_{J_{BC},l} |\mathcal{M}_{A\to BC}(k_0; J_{BC}, l)|^2$$

$$\mathcal{M}_{A\to BC} = M_{A\to BC} + (-1)^{I_B+I_C-I_A+J_B+J_C-J_{BC}+l} M_{A\to CB}$$

$$M_{A\to BC} = \mathcal{I}_{color}\ \mathcal{I}_{flavor}\ (\mathcal{I}_{signature}\ \mathcal{I}_{spin-space})$$

- Color term

$$\mathcal{I}_{color} = \frac{1}{3^{\frac{3}{2}}} \sum_a \mathrm{Tr}\left[\frac{\lambda^a}{2}\frac{\lambda^a}{2}\right] = \frac{4}{3^{\frac{3}{2}}}$$

- Flavor term

$$\mathcal{I}_{flavor} = (-1)^{t_\alpha+t_\beta+I_A} \delta_{f_\alpha f_\delta} \delta_{f_\beta f_\rho} \delta_{f_\mu f_\lambda} \delta_{f_\nu f_\epsilon} \sqrt{(2I_B+1)(2I_C+1)(2t_\mu+1)} \begin{Bmatrix} t_\beta & I_C & t_\mu \\ I_B & t_\alpha & I_A \end{Bmatrix}$$

4.- Microscopic decay model

4.3.- Some Formulas (Continuation)

- Spin-space term

$$\mathcal{I}_{spin-space} = \frac{-2}{\sqrt{1+\delta_{BC}}} \int d^3K_B d^3K_C \sum_{m,M_{BC}} \langle J_{BC} M_{BC} lm | J_A M_A \rangle \, \delta^{(3)}(\vec{K} - \vec{K}_0) \delta(k - k_0)$$

$$\frac{Y_{lm}(\hat{k})}{k} \sum_{M_B,M_C} \langle J_B M_B J_C M_C | J_{BC} M_{BC} \rangle \int d^3p_\delta \, d^3p_\epsilon \, d^3p_\lambda \, d^3p_\rho \, \delta^{(3)}(\vec{K}_B - \vec{P}_B)$$

$$\delta^{(3)}(\vec{K}_C - \vec{P}_C) \phi_B(\vec{p}_B) \phi_C(\vec{p}_C) \delta_{\rho\beta} \delta^{(3)}(\vec{p}_\rho - \vec{p}_\beta) \delta^{(3)}(\vec{p}_\lambda + \vec{p}_\epsilon + \vec{p}_\delta - \vec{p}_\alpha)$$

$$K(|\vec{p}_\lambda + \vec{p}_\epsilon|) \lim_{v/c \to 0} [\bar{u}_\lambda(\vec{p}_\lambda) \Gamma v_\epsilon(\vec{p}_\epsilon)] \lim_{v/c \to 0} [\bar{u}_\delta(\vec{p}_\delta) \Gamma u_\alpha(\vec{p}_\alpha)]$$

$$\int d^3p_\alpha \, d^3p_\beta \, \delta^{(3)}(\vec{P}_A) \phi_A(\vec{p}_A)$$

4.- Microscopic decay model

4.4.- The $^3P_0$ model

$$H_I = g \int d^3x \, \bar{\psi}(\vec{x}) \, \psi(\vec{x})$$

- Color term $\Rightarrow \mathcal{I}_{color} = \frac{1}{\sqrt{3}}$
- Flavor term $\Rightarrow$

$$\mathcal{I}_{flavor} = (-1)^{t_\alpha + t_\beta + I_A} \delta_{f_\alpha f_\delta} \delta_{f_\beta f_\rho} \delta_{f_\mu f_\lambda} \delta_{f_\nu f_\epsilon} \sqrt{(2I_B+1)(2I_C+1)(2t_\mu+1)} \begin{Bmatrix} t_\beta & I_C & t_\mu \\ I_B & t_\alpha & I_A \end{Bmatrix}$$

- Spin-space term $\Rightarrow$

$$\mathcal{I}_{spin-space} = \frac{1}{\sqrt{1+\delta_{BC}}} \int d^3K_B d^3K_C d^3p_\alpha d^3p_\beta d^3p_\mu d^3p_\nu \delta^{(3)}(\vec{K} - \vec{K}_0)$$
$$\delta^{(3)}(\vec{K}_B - \vec{P}_B)\delta^{(3)}(\vec{K}_C - \vec{P}_C)\delta^{(3)}(\vec{p}_\mu + \vec{p}_\nu)\delta^{(3)}(\vec{P_A}) \frac{\delta(k-k_0)}{k}$$
$$\langle \{ [[\phi_B(\vec{p}_B)(s_\alpha s_\nu)S_B] \, J_B \, [\phi_C(\vec{p}_C)(s_\mu s_\beta)S_C] \, J_C] \, J_{BC} \, Y_l(\hat{k})\} \, J_A |$$
$$\{[\phi_A(\vec{p}_A)(s_\alpha s_\beta)S_A] \, J_A \, [\gamma_{\mu,(1)} \left(\frac{\vec{p}_\mu - \vec{p}_\nu}{2}\right) (s_\mu s_\nu)1] \, 0\} \, J_A \rangle$$

5.- Results within charmonium sector

5.1.- Comparative with other microscopic models: $\psi(3770) \longrightarrow DD$ decay

Prediction from Phys. Rev. D **73** *014014 (2006)*

$$\Gamma(\psi(3770) \rightarrow DD) = 20.1\,\mathrm{MeV}$$

Prediction using the model of E.S. Ackleh et al.

$$\Gamma(\psi(3770) \rightarrow DD) = 104.0\mathrm{MeV}$$

Prediction with a mixture of scalar-vector screened confinement

$$\Gamma(\psi(3770) \rightarrow DD) = 19.0\mathrm{MeV}$$

5.- Results within charmonium sector

5.2.- Comparative with other microscopic models (Continuation)

- *We can calculate the matrix elements taking into account the different Lorentz structures*
- *We can generalize the dependence of the kernel with the interquark distance*

Comparative of the $j^0 K j^0$ term

Decay	Cornell Model	Our model
$\psi(3770) \to DD$	20.1	29.8
$\psi(4040) \to DD$	0.1	1.4
$\psi(4040) \to DD^*$	33.0	25.2
$\psi(4040) \to D^*D^*$	33.0	35.0
$\psi(4040) \to D_sD_s$	8.0	0.3
total	74.0	61.9
$\psi(4160) \to DD$	3.2	25.0
$\psi(4160) \to DD^*$	6.9	0.5
$\psi(4160) \to D^*D^*$	41.9	21.3
$\psi(4160) \to D_sD_s$	5.6	0.03
$\psi(4160) \to D_sD_s^*$	11.0	0.6
total	69.2	47.4

State	Ratio	Cornell	$j^0 K j^0$	Our model	$^3P_0$	Measured
$\psi(4040)$	$D\bar{D}/D\bar{D}^*$	0.003	0.06	0.54	0.21	$0.24 \pm 0.05 \pm 0.12$
	$D^*\bar{D}^*/D\bar{D}^*$	1.00	1.39	0.48	3.70	$0.18 \pm 0.14 \pm 0.03$
$\psi(4160)$	$D\bar{D}/D^*\bar{D}^*$	0.08	1.17	3.23	0.27	$0.02 \pm 0.03 \pm 0.02$
	$D\bar{D}^*/D^*\bar{D}^*$	0.16	0.02	1.40	0.03	$0.34 \pm 0.14 \pm 0.05$
$X(4360)$	$D\bar{D}/D^*\bar{D}^*$	-	0.40	0.12	0.90	$0.14 \pm 0.12 \pm 0.03$
	$D\bar{D}^*/D^*\bar{D}^*$	-	0.08	0.64	0.92	$0.17 \pm 0.25 \pm 0.03$
$\psi(4415)$	$D\bar{D}/D^*\bar{D}^*$	-	1.54	1.10	0.46	$0.14 \pm 0.12 \pm 0.03$
	$D\bar{D}^*/D^*\bar{D}^*$	-	0.28	0.92	0.18	$0.17 \pm 0.25 \pm 0.03$

5.- Results within charmonium sector

5.2.- Excited states

J. Segovia, D. R. Entem and F. Fernández, Phys. Rev. D **78**, 114033 (2008)

Meson	State	channel	$\Gamma_{^3P_0}$	$\mathcal{B}_{^3P_0}$	Γ	$\mathcal{B}$
$\psi(3770)$	1^3D_1	D^+D^-	9.49	42.8	8.03	42.3
		$D^0\bar{D}^0$	12.66	57.2	10.94	57.7
22.4 ± 2.5 (PDG2006)		DD	22.15	100	18.97	100
27.6 ± 1.0 (PDG2010)		total	22.15		18.97	
$\psi(4040)$	3^3S_1	DD	3.86	4.1	10.17	26.0
		DD^*	18.60	20.0	18.75	47.9
		D^*D^*	68.90	74.0	9.06	23.2
		D_sD_s	1.74	1.9	1.14	2.9
80 ± 10		total	93.10		39.12	
$\psi(4160)$	2^3D_1	DD	19.09	19.7	17.03	52.1
		DD^*	1.86	1.9	7.38	22.6
		D^*D^*	70.06	72.2	5.28	16.2
		D_sD_s	0.20	0.2	2.61	7.9
		$D_sD_s^*$	5.81	6.0	0.40	1.2
103 ± 8		total	97.02		32.70	

5.- Results within charmonium sector

5.2.- Excited states (Continuation)

Meson	State	channel	$\Gamma_{^3P_0}$	$\mathcal{B}_{^3P_0}$	Γ	$\mathcal{B}$
$X(4360)$	4^3S_1	DD	6.71	7.0	5.73	5.6
		DD^*	6.85	7.2	29.81	29.2
		D^*D^*	7.42	7.8	46.46	45.5
		DD_1	45.61	47.8	2.18	2.1
		DD_1'	3.59	3.8	12.02	11.7
		DD_2^*	22.73	23.8	0.56	0.6
		D_sD_s	0.06	0.1	1.86	1.8
		$D_sD_s^*$	1.59	1.7	3.36	3.3
		$D_s^*D_s^*$	0.76	0.8	0.17	0.2
$74 \pm 15 \pm 10$		total	95.32		102.15	
$\psi(4415)$	3^3D_1	DD	12.64	9.5	7.93	18.5
		DD^*	4.87	3.7	6.66	15.6
		D^*D^*	27.24	20.5	7.23	16.9
		DD_1	54.19	40.7	6.06	14.2
		DD_1'	5.79	4.4	2.12	5.0
		DD_2^*	19.75	14.8	1.82	4.3
		$D^*D_0^*$	5.96	4.5	2.39	5.6
		D_sD_s	0.26	0.2	2.22	5.2
		$D_sD_s^*$	0.57	0.4	1.09	2.5
		$D_s^*D_s^*$	1.78	1.3	5.20	12.2
62 ± 20		total	133.05		42.72	

5.- Results within charmonium sector

5.2.- Excited states (Continuation)

Meson	State	channel	$\Gamma_{^3P_0}$	$\mathcal{B}_{^3P_0}$	Γ	$\mathcal{B}$
$X(4630)$	5^3S_1	DD	5.54	3.2	1.44	0.8
		DD^*	21.95	12.7	15.82	8.4
		D^*D^*	13.03	7.5	30.40	16.2
		DD_1	2.41	1.4	18.70	9.9
		DD_1'	3.78	2.2	2.58	1.4
		DD_2^*	0.0	0.0	21.14	11.2
		$D^*D_0^*$	5.83	3.4	10.10	5.4
		D^*D_1	32.81	19.0	22.47	11.9
		D^*D_1'	12.01	7.0	26.24	13.9
		$D^*D_2^*$	67.33	39.0	18.28	9.7
		D_sD_s	0.77	0.4	1.28	0.7
		$D_sD_s^*$	0.25	0.1	6.70	3.6
		$D_s^*D_s^*$	0.95	0.6	6.34	3.4
		D_sD_{s1}	2.36	1.4	0.92	0.5
		D_sD_{s1}'	0.66	0.4	0.03	0.0
		$D_sD_{s2}^*$	0.16	0.1	0.22	0.1
		$D_s^*D_{s0}^*$	2.31	1.3	1.30	0.7
		$D_s^*D_{s1}$	0.12	0.1	3.74	2.0
		$D_s^*D_{s1}'$	0.22	0.1	0.29	0.1
		$D_{s0}^*D_{s0}^*$	0.18	0.1	0.23	0.1
92^{+40+10}_{-24-21}		total	172.67		188.22	

5.- Results within charmonium sector

5.2.- Excited states (Continuation)

Meson	State	channel	$\Gamma_{^3P_0}$	$\mathcal{B}_{^3P_0}$	Γ	$\mathcal{B}$
$X(4660)$	4^3D_1	DD	9.14	8.1	3.21	2.3
		DD^*	6.32	5.6	4.10	2.9
		D^*D^*	31.83	28.2	2.67	1.9
		DD_1	2.02	1.8	20.51	14.4
		DD_1'	0.43	0.4	2.62	1.8
		DD_2^*	0.0	0.0	6.75	4.8
		$D^*D_0^*$	2.88	2.5	0.71	0.5
		D^*D_1	29.14	25.8	10.89	7.7
		D^*D_1'	5.84	5.1	2.96	2.1
		$D^*D_2^*$	18.34	16.2	77.52	54.5
		D_sD_s	0.80	0.7	1.46	1.0
		$D_sD_s^*$	0.0	0.0	1.35	0.9
		$D_s^*D_s^*$	0.28	0.2	4.28	3.0
		D_sD_{s1}	3.04	2.7	0.0	0.0
		D_sD_{s1}'	0.91	0.8	0.62	0.4
		$D_sD_{s2}^*$	0.07	0.1	0.07	0.1
		$D_s^*D_{s0}^*$	0.99	0.9	0.43	0.3
		$D_s^*D_{s1}$	0.40	0.4	0.93	0.6
		$D_s^*D_{s1}'$	0.14	0.1	0.37	0.3
		$D_{s0}^*D_{s0}^*$	0.44	0.4	0.74	0.5
$48 \pm 15 \pm 3$		total	113.01		142.19	

6.- Summary

- We have studied the charmonium strong decays to open-charm mesons using a QCD based model
- Very poor understood area because it is a non-perturbative process $\longrightarrow$ Few previous works
  - E. Eichten *et al.* Phys. Rev. D **17** 3090 (1978); **21** 203 (1980) $\longrightarrow$ update: Phys. Rev. D **73** 014014 (2006)
  - E.S. Ackleh *et al.* Phys. Rev. D **54**, 6811 (1996)
  - Very recent works: Yu.A. Simonov arXiv:1103.4028v1 [hep-ph] 21 Mar 2011 and Bao-Fei Li *et al.* arXiv:1105.1620v1 [hep-ph] 9 May 2011
- A pure scalar linear confining interaction, which is generally accepted, predicts large widths
- A static vector linear confining interaction predicts a reasonable widths
- Using a mixture of scalar-vector linear screened confining interaction $\longrightarrow$ we also obtain the correct order of magnitude
- It is difficult to draw conclusions due to the limited experimental data