The predictions of $\psi(nS)$ and $\Upsilon(nS)$ decays based on the molecular structure

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THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Theoretical Physics

Tests on the molecular structure of $f_2(1270)$, $f_2'(1525)$ from $\psi(nS)$ and $\Upsilon(nS)$ decays

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Abstract. Based on previous studies that support the vector-vector molecular structure of the $f_2(1270)$, $f_2'(1525)$, $\bar{K}_2^{*0}(1430)$, $f_0(1370)$ and $f_0(1710)$ resonances, we make predictions for the $\psi(2S)$ decay into $\omega(\phi)f_2(1270)$, $\omega(\phi)f_2'(1525)$, $K^{*0}(892)\bar{K}_2^{*0}(1430)$ and the radiative decay of $\Upsilon(1S), \Upsilon(2S), \psi(2S)$ into $\gamma f_2(1270)$, $\gamma f_2'(1525)$, $\gamma f_0(1370)$, $\gamma f_0(1710)$. Agreement with experimental data is found for three available ratios, without using free parameters, and predictions are done for other cases.

Outline

1. Motivation

2. Chiral unitary approach

dynamically generated states

3. J/ψ decays (previous work)

- Hadronic decays $J/\psi \to VT$
- Radiative decays $J/\psi \to \gamma T$

4 $\psi(nS)$ and $\Upsilon(nS)$ decays (present work)

- Hadronic decays $\Longrightarrow$ $\psi(nS) \to VT$
- Radiative decays $\Longrightarrow$ $\psi(nS), \Upsilon(nS) \to \gamma T$

5. Summary

1. Motivation

a) Hadronic decay

J/ψ decays $\Longrightarrow$

good tool **to study the nature of some resonances, in particular those generated dynamically from the interaction of pairs of more elementary hadrons**

Pioneering work $\Longrightarrow$

$J/\psi \to VS$

The study of J/ψ decay into ϕ or ω and a scalar meson $\sigma(600)$ and $f_0(980)$

Scalar Resonance

The idea is that there is a primary J/ψ decay into a vector meson (ϕ or ω) and a pair of pseudoscalar mesons (PP) in a scalar state.

$J/\psi \to VS$

Nucl. Phys. A 679, 671 (2001); Nucl. Phys. A 744, 127 (2004);Phys. Rev. D 74, 034021 (2006); Eur. Phys. J. C63, 93(2009)

- **As a test of chiral dynamics and the dynamically generated character of the low lying scalar resonances.**
- **The reaction offers a genuine simplifying factor since the** J/ψ, a $c\bar{c}$ state, qualifies as a singlet of SU(3).

Eur. Phys. J. C63, 93(2009); Nucl.Phys.A 620, 438 (1997); Phys.Rev.D59, 074001(1999);Eur.Phys.J.A 3, 307 (1998); Eur.Phys.J.A8, 389 (2000); Phys. Rev. Lett.97, 242002 (2006); Nucl.Phys.A679, 57 (2000)

Good representation of the experimental data

Then

R. Molina, D. Nicmorus and E. Oset, Phys. Rev. D 78, 114018 (2008)

(The $\rho\rho$ interaction in the hidden gauge formalism and the $f_0(1370)$ and $f_2(1270)$ resonances)

An extension to SU(3)

L.S. Geng and E. Oset, Phys. Rev. D 79, 074009 (2009)

(Vector meson-vector meson interaction in a hidden gauge unitary approach.)

$\Longrightarrow$ **11 states dynamically generated, including $f_2(1270), f_2'(1525), \bar{K}_2^{*0}(1430), f_0(1370), f_0(1710)$ resonances by a pair of vector mesons (VV) interaction**

Chiral unitary approach

Analogous to $J/\psi \to VS \Longrightarrow$ extended $J/\psi \to VT$

A. Martinez Torres, L.S. Geng, L.R. Dai, B.X. Sun, E. Oset, B.S. Zou, Phys. Lett . B 680 (2009) 310

Extended work $\Longrightarrow$ $J/\psi \to VT$

Study of the $J/\psi \to \phi(\omega) f_2(1270)$, $J/\psi \to \phi(\omega) f_2'(1525)$ and $J/\psi \to K^{*0}(892)\bar{K}_2^{*0}(1430)$ decays

Tensor Resonance

The idea is that there is a primary J/ψ decay into a vector meson (ϕ or ω or $K^{*0}(892)$) and a pair of vector mesons (VV) in a tensor state.

Our results can reasonably describe the experimental data

We hope to extend $\psi(nS) \to VT$

b) Radiative decay

L.S. Geng, F.K. Guo, C. Hanhart, R. Molina, E. Oset, B.S.Zou, Eur. Phys. J. A 44, 305 (2010)

$J/\psi \rightarrow \gamma T$ or γS **Study of the $f_2(1270)$, $f'_2(1525)$, $f_0(1370)$ and $f_0(1710)$ in the J/ψ radiative decays**

Here the $f_2(1270)$, $f'_2(1525)$, $f_0(1370)$, $f_0(1710)$ are dynamically generated resonances.

Results:
Ratio of the rates in the production of the tensor mesons is in good agreement with experiment data.

Here the molecular picture can describe the decay ratios well

Prediction of scalar mesons, which could be tested in the future

⇨ We hope to further test $\psi(nS)$ and $\Upsilon(nS)$ decays

2. Chiral unitary approach

dynamically generated states

The resonances were obtained by solving the Bethe Salpeter equation in coupled channels to obtain the scattering matrix

$$T = [1 - \tilde{V} G]^{-1} \tilde{V}$$

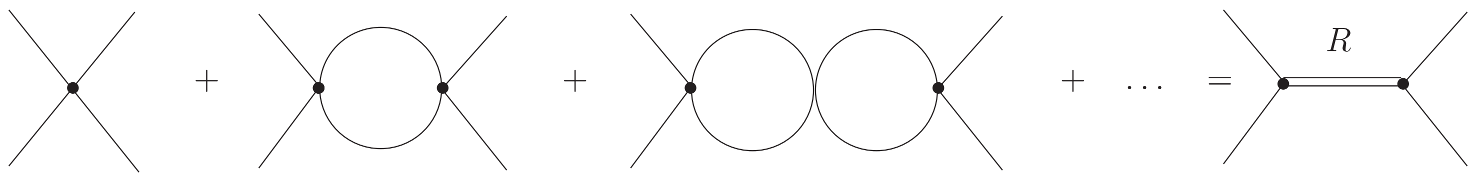

Fig.1 Diagrammatical representation

where $\tilde{V}$ is the transition potential from $V'V' \to V'V'$ and G is the loop function of two mesons.

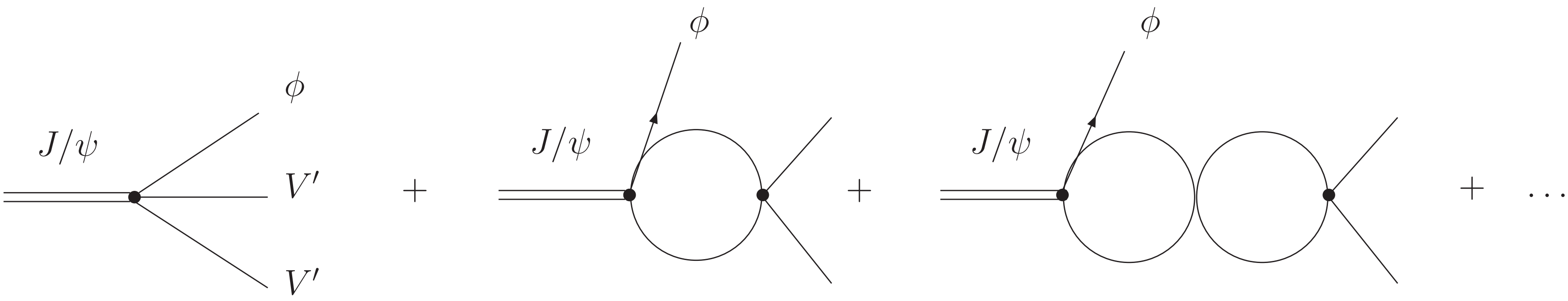

Fig.2 Production mechanism of ϕ and two interacting vector mesons

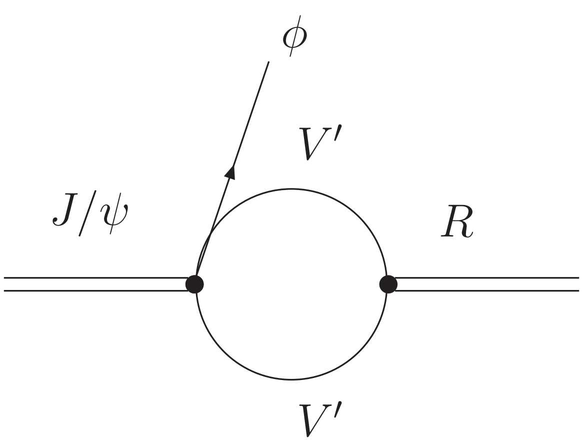

Fig.3 Selection of diagrams of Fig.2 that go into resonance formation, omitting the coupling to $V'V'$ without interaction.

R. Molina, D. Nicmorus and E. Oset, Phys. Rev. D 78, 114018 (2008); L. S. Geng and E. Oset, Phys. Rev. D 79, 074009 (2009)

(Vector meson-vector meson interaction in a hidden gauge unitary approach.)

Employing the coupled channel Bethe-Salpeter equation to unitarize the tree-level transition amplitudes obtained from the hidden-gauge Lagrangians.

$\Longrightarrow$ There are 11 states dynamically generated, including $f_2(1270)$, $f_2'(1525)$, $\bar{K}_2^{*0}(1430)$, $f_0(1370)$, $f_0(1710)$ resonances.

3. J/ψ decays

$J/\psi \to VT$

A. Martinez Torres, L.S. Geng, L.R. Dai, B.X. Sun, E. Oset, B.S. Zou, Phys. Lett . B 680 (2009) 310)

- **The assumption**

These tensor states are all dynamically generated resonances from the vector-vector interaction provided by the hidden gauge formalism, upon unitarization in coupled channels.

a) Formalism J/ψ decay into $\phi(\omega)VV \to \phi(\omega)T$

$\Longrightarrow$ We study the $J/\psi \to VV'V'$ process,where $V'V'$ are the pairs of vector mesons that lead to the desired resonances.

Transition matrix

$$t_{J/\psi\to\phi R} = \sum_j W_j^{(\phi)} G_j \; g_j$$

G_j: loop function of two meson propagators

g_j: couplings of the resonances to the different vector-vector channels

Phys. Rev. D 79, 074009 (2009)

W_j : The evaluation of primary weights for J/ψ decay into $\phi, \omega, K^{*0}(892)$ plus a pair of the vector building blocks of the resonances

Phys. Lett . B 680 (2009) 310

G_j and g_j are obtained

L.S. Geng and E. Oset, Phys. Rev. D 79, 074009 (2009)

Couplings and values of the loop functions for the different channels at the resonance energy.

		$\rho\rho$	$K^*\bar{K}^*$	$\omega\omega$	$\phi\phi$	$\rho\bar{K}^*$	$\omega\bar{K}^{*0}$	$\phi\bar{K}^{*0}$
$f_2(1270)$	g_i (MeV)	10551	4771	−503	−771	0	0	0
	error g_i(%)	4	3	22	22	0	0	0
	$G_i(\times 10^{-3})$	−4.74	−3.00	−4.97	0.475	0	0	0
	error G_i(%)	10	29	42	220	0	0	0
$f_2'(1525)$	g_i (MeV)	−2611	9692	−2707	−4611	0	0	0
	error g_i(%)	12	6	2	2	0	0	0
	$G_i(\times 10^{-3})$	−8.67	−4.98	−9.63	−0.710	0	0	0
	error G_i(%)	6	17	19	141	0	0	0
$\bar{K}_2^{*0}(1430)$	g_i (MeV)	0	0	0	0	10613	2273	−2906
	error g_i(%)	0	0	0	0	3	5	5
	$G_i(\times 10^{-3})$	0	0	0	0	−6.41	−5.94	−2.70
	error G_i(%)	0	0	0	0	12	19	43

Theoretical error estimates

The estimation of the theoretical errors has been done by changing some parameters of the theory (g_v and subtraction constants)

Phys. Lett . B 680 (2009) 310

By taking ω, ϕ to be ideal mixtures of singlet and octet SU(3) states, and the amplitudes of J/ψ decay will involve matrix elements of $T^{(1,1)}$ and $T^{(8,8)}$.

A. Martinez Torres, L.S. Geng, L.R. Dai, B.X. Sun, E. Oset, B.S. Zou, Phys. Lett . B 680 (2009) 310)

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Study of the $J/\psi \to \phi(\omega) f_2(1270)$, $J/\psi \to \phi(\omega) f_2'(1525)$ and $J/\psi \to K^{*0}(892)\bar{K}_2^{*0}(1430)$ decays

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ABSTRACT

We present an approach to study the decay modes of the J/ψ into a vector meson and a tensor meson, taking into account the nature of the $f_2(1270)$, $f_2'(1525)$, $\bar{K}_2^{*0}(1430)$ resonances as dynamically generated states from the vector meson-vector meson interaction. We evaluate four ratios of partial decay widths in terms of a flavor dependent OZI breaking parameter and the results obtained compare favorably with experiment, although the experimental uncertainties are still large. Further refinements of the data would provide a more stringent test on the theoretical approach. The fit to the data is possible due to the particular strength and sign of the couplings of the resonances to pairs of vector mesons given by the theory.

$$\phi = s\bar{s} = \sqrt{\frac{1}{3}}V_1 - \sqrt{\frac{2}{3}}V_8$$

$$\omega = \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) = \sqrt{\frac{2}{3}}V_1 + \sqrt{\frac{1}{3}}V_8$$

The ratio of amplitudes

$$\nu = \frac{T^{(1,1)}}{T^{(8,8)}}$$

Weights W_i for $J/\psi \to \phi(\omega)V'V'$ in $I = 0$.

	$\rho\rho$	$K^*\bar{K}^*$	$\omega\omega$	$\phi\phi$
$W^{(\phi)}$	$-\frac{1}{\sqrt{6}}(\nu-1)$	$-\frac{\sqrt{2}}{6}(2\nu+1)$	$\frac{1}{3\sqrt{2}}(\nu-1)$	$\frac{1}{3\sqrt{2}}(\nu+2)$
$W^{(\omega)}$	$-\frac{1}{2\sqrt{3}}(2\nu+1)$	$-\frac{1}{6}(4\nu-1)$	$\frac{1}{6}(2\nu+1)$	$\frac{1}{3}(\nu-1)$

Weights for $J/\psi \to K^{*0}V'V'$ in $I = 1/2$, $I_3 = 1/2$

	$\rho\bar{K}^*$	$\bar{K}^*\omega$	$\bar{K}^*\phi$
$W^{(K^{*0})}$	$\sqrt{\frac{3}{2}}$	$\sqrt{\frac{1}{2}}$	1

The evaluation of the primary weights

1) J/ψ as a singlet of SU(3)

2) ideal mixing for the ϕ ω states.

Experimental branching ratios

$J/\psi \to VT$

	Obtained from	$BR[\times 10^{-3}]$
$J/\psi \to \omega f_2(1270)$	PDG	4.3±0.6
$J/\psi \to \phi f_2(1270)$	BES	0.27±0.06
$J/\psi \to \omega f_2'(1525)$	PDG	<0.2
$J/\psi \to \phi f_2'(1525)$	BES	0.82±0.12
$J/\psi \to K^{*0}\bar{K}_2^{*0}(1430)$	PDG	3.0±0.3

PDG: Phys. Lett . B 667 (2008) 1

BES: Phys. Lett . B 607 (2005) 243

$$R_1 \equiv \frac{\Gamma_{J/\psi\to\phi f_2(1270)}}{\Gamma_{J/\psi\to\phi f_2'(1525)}}, \qquad R_2 \equiv \frac{\Gamma_{J/\psi\to\omega f_2(1270)}}{\Gamma_{J/\psi\to\omega f_2'(1525)}},$$

$$R_3 \equiv \frac{\Gamma_{J/\psi\to\omega f_2(1270)}}{\Gamma_{J/\psi\to\phi f_2(1270)}}, \qquad R_4 \equiv \frac{\Gamma_{J/\psi\to K^{*0}\bar{K}_2^{*0}(1430)}}{\Gamma_{J/\psi\to\omega f_2(1270)}}.$$

A. Martinez Torres, L.S. Geng, L.R. Dai, B.X. Sun, E. Oset, B.S.Zou, Phys. Lett . B 680 (2009) 310

The idea these tensor states are all dynamically generated from the vector-vector interaction

The J/ψ decay widths

$$\Gamma = \frac{1}{8\pi}\frac{1}{M_{J/\psi}^2}|t|^2 q$$

with q the momentum of the $\phi(\omega, K^{*0})$ in the J/ψ rest frame.

Upon minimization of the χ^2 function

$\Longrightarrow \nu = 1.45$ of best fit

	Experiment	Theory
R_1	0.22 - 0.47 $(0.33^{+0.14}_{-0.11})$	0.13 - 0.61 $(0.28^{+0.33}_{-0.15})$
R_2	12.33 - 49.00 $(21.50^{+27.50}_{-9.17})$	2.92 - 13.58 $(5.88^{+7.70}_{-2.96})$
R_3	11.21 - 23.08 $(15.85^{+7.23}_{-4.65})$	6.18 - 19.15 $(10.63^{+8.52}_{-4.45})$
R_4	0.55 - 0.89 $(0.70^{+0.19}_{-0.15})$	0.83 - 2.10 $(1.33^{+0.77}_{-0.50})$

Theoretical errors

1) average mass of the vector nonet and average decay constant of the pion octet

2) slightly change the values of the subtraction constants

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Our results

the overall agreement with data is reasonable, obtaining **four independent ratios** with just **one** parameter

b) J/ψ radiative decay into $\gamma VV \to \gamma T$

L.S. Geng, F.K. Guo, C. Hanhart, R. Molina, E. Oset, B.S.Zou, Eur. Phys. J. A 44, 305 (2010)

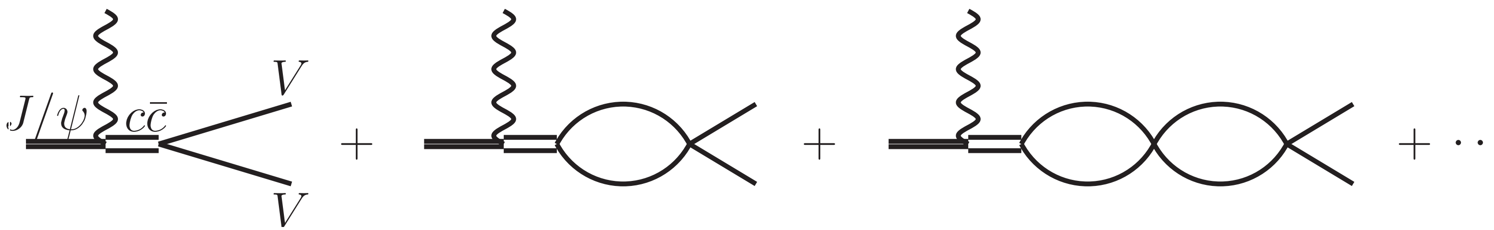

Fig.4 Schematic representation of J/ψ decay into a photon and one dynamically generated resonance

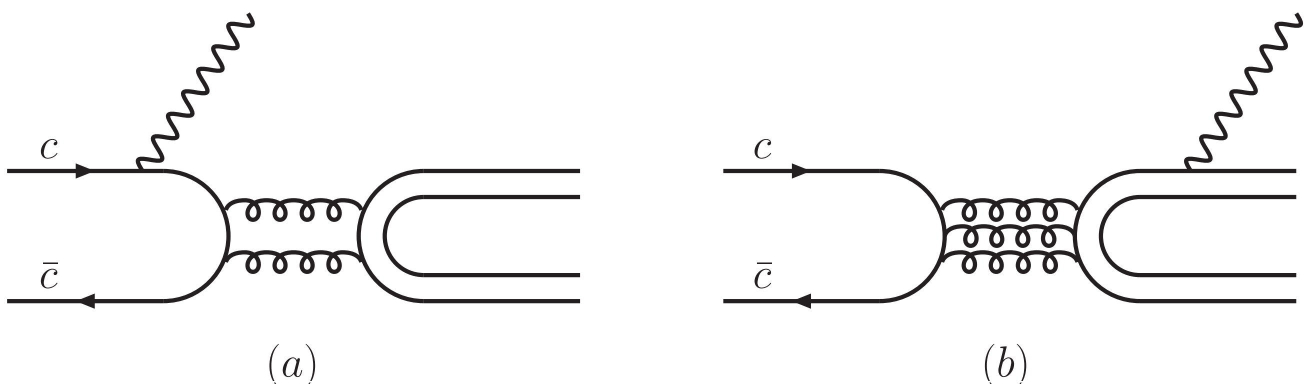

Fig.5 Two mechanisms of the J/ψ radiative decays

$J/\psi \to \gamma T$

- **The assumption**

These tensor states are all dynamically generated resonances from the vector-vector interaction provided by the hidden gauge formalism, upon unitarization in coupled channels.

- **Formalism**

$\Longrightarrow$ We study the $J/\psi \to \gamma V'V'$ process,where $V'V'$ are the pairs of vector mesons that lead to the desired resonances.

Transition matrix

$$t_{J/\psi\to\gamma R} = \sum_j \widetilde{W}_j G_j \, g_j$$

G_j: loop function of two meson propagators

g_j: couplings of the resonances to the different vector-vector channels

Phys. Rev. D 79, 074009 (2009)

$\widetilde{W}_j$: The primary weights for J/ψ radiative decay

L.S. Geng, F.K. Guo, C. Hanhart, R. Molina, E. Oset, B.S.Zou, Eur. Phys. J. A 44, 305 (2010)

Eur. Phys. J. A 44, 305–311 (2010)
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Regular Article – Theoretical Physics

Study of the $f_2(1270)$, $f_2'(1525)$, $f_0(1370)$ and $f_0(1710)$ in the J/ψ radiative decays

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Abstract. In this paper we present an approach to study the radiative decay modes of the $J/$ photon and one of the tensor mesons $f_2(1270)$, $f_2'(1525)$, as well as the scalar ones $f_0(1370)$ and Especially, we compare predictions that emerge from a scheme where the states appear dynamica solution of vector meson–vector meson scattering amplitudes to those from a (admittedly nai model. We provide evidence that it might be possible to distinguish amongst the two scenar improved data are available.

$$R_T = \frac{\Gamma_{J/\psi\to\gamma f_2(1270)}}{\Gamma_{J/\psi\to\gamma f_2'(1525)}};$$

$$R_S = \frac{\Gamma_{J/\psi\to\gamma f_0(1370)}}{\Gamma_{J/\psi\to\gamma f_0(1710)}},$$

	Molecular picture	Exp
$R_T\ (J/\psi)$	2 ± 1	$3.18^{+0.58}_{-0.64}$
$R_S\ (J/\psi)$	1.2 ± 0.3	

Exp: Phys. Rev. D 86, 010001 (2012)1

Ratio of the rates in the production of the tensor mesons is in good agreement with experiment

Prediction of scalar mesons, which could be tested in the future

4. $\psi(nS)$ and $\Upsilon(nS)$ decays

Our aim: to test the hypothesis

about the molecular nature of $f_2(1270), f_2'(1525)$, $\bar{K}_2^{*0}(1430)$ $f_0(1370), f_0(1710)$ as dynamically generated states of vector meson-vector meson interaction

by testing all reactions possible

J/ψ, $\psi(2S)$ } $c\bar{c}$ state

$\Upsilon(1S)$, $\Upsilon(2S)$ } $b\bar{b}$ state

The arguments used to make predictions are very simple and general and can be easily extended to the decays of $\psi(nS)$ and $\Upsilon(nS)$

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Tests on the molecular structure of $f_2(1270)$, $f_2'(1525)$ from $\psi(nS)$ and $\Upsilon(nS)$ decays

1) Hadronic decays

Transition matrix

$$t_{\psi(ns)\to\phi R} = \sum_j W_j^{(\phi)} G_j \; g_j$$

- $G_j \Longrightarrow V'V'$ loop functions
- $g_j \Longrightarrow$ couplings of whichever resonance to the corresponding $V'V'$ channel j
- $W_j^{(\phi)} \Longrightarrow$ weights

Phys. Lett . B 680 (2009) 310)

The decay widths

$$\Gamma = \frac{1}{8\pi}\frac{1}{M^2_{\psi(ns)}}|t|^2 q$$

with q the momentum of the $\phi(\omega, K^{*0})$ in the $\psi(ns)$ rest frame.

Similarly

$$\begin{cases} \psi(ns) \to \omega R \\ \psi(ns) \to K^{*0} R \end{cases}$$

$\psi(2s) \to VT$

Experimental branching ratios

	Obtained from	$BR[\times 10^{-4}]$
$\psi(2s) \to \omega f_2(1270)$	PDG	2.2 ± 0.4
$\psi(2s) \to \phi f_2'(1525)$	PDG	0.44 ± 0.16
$\psi(2s) \to K^{*0}(892)\bar{K}_2^{*0}(1430)$	PDG	1.9 ± 0.5

PDG **Phys. Rev. D 86, 010001 (2012)**

$$\widetilde{R_1} \equiv \frac{\Gamma_{\psi(2S)\to\phi f_2(1270)}}{\Gamma_{\psi(2S)\to\phi f_2'(1525)}}, \quad \widetilde{R_2} \equiv \frac{\Gamma_{\psi(2S)\to\omega f_2(1270)}}{\Gamma_{\psi(2S)\to\omega f_2'(1525)}},$$

$$\widetilde{R_3} \equiv \frac{\Gamma_{\psi(2S)\to\omega f_2(1270)}}{\Gamma_{\psi(2S)\to\phi f_2(1270)}}, \quad \widetilde{R_4} \equiv \frac{\Gamma_{\psi(2S)\to K^{*0}\bar{K}_2^{*0}(1430)}}{\Gamma_{\psi(2S)\to\omega f_2(1270)}}.$$

Experiment **Phys. Rev. D 86, 010001 (2012)**

	Experiment	Theory
$\widetilde{R_1}$		0.12-0.56 $(0.26^{+0.30}_{-0.14})$
$\widetilde{R_2}$		2.76-12.82$(5.55^{+7.27}_{-2.79})$
$\widetilde{R_3}$		5.91-18.30$(10.16^{+8.14}_{-4.25})$
$\widetilde{R_4}$	0.54-1.33 $(0.86^{+0.47}_{-0.32})$	0.88-2.22 $(1.41^{+0.82}_{-0.53})$
$\widetilde{R_1} \cdot \widetilde{R_3}$	3.0-9.3 $(5.0^{+4.3}_{-2.0})$	1.24-5.74 $(2.64^{+3.1}_{-1.4})$

test on the molecular nature

The agreement with experiment for the available data is good

Prediction done for ratios not yet measured

2) Radiative decays

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Transition matrix

$$t_{\psi(ns)\to\gamma R} = \sum_j \widetilde{W}_j G_j \, g_j$$

- $G_j \Longrightarrow V'V'$ loop functions
- $g_j \Longrightarrow$ couplings of whichever resonance to the corresponding $V'V'$ channel j
- $\widetilde{W}_j \Longrightarrow$ weights

Eur. Phys. J. A 44, 305 (2010)

The decay widths

Similarly for $\Upsilon(ns) \to \gamma R$

$$\Gamma = \frac{1}{8\pi}\frac{1}{M^2_{\psi(ns)}}|t|^2 q$$

with q the momentum of the photon in the $\psi(ns)$ rest frame.

Extend to heavy quarkonium states

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J/ψ ➡ $\Upsilon(1S)$

Test on the molecular nature

$$\widetilde{R_T} = \frac{\Gamma_{\Upsilon(1S)\to\gamma f_2(1270)}}{\Gamma_{\Upsilon(1S)\to\gamma f_2'(1525)}}; \quad \widetilde{R_S} = \frac{\Gamma_{\Upsilon(1S)\to\gamma f_0(1370)}}{\Gamma_{\Upsilon(1S)\to\gamma f_0(1710)}},$$

	Molecular picture	Exp
$\widetilde{R_T}$ $(\Upsilon(1S))$	1.84 ± 0.92	$2.66^{+1.13}_{-0.70}$
$\widetilde{R_S}$ $(\Upsilon(1S))$	1.05 ± 0.26	

Prediction

Exp CLEO Collaboration
Phys. Rev. D 75, 072001 (2007);Phys. Rev. D 83,037101 (2011); Phys. Rev. D 73,032001 (2006)

Results the agreement with the experimental ratio is good

Extend to $\psi(2S)$ and $\Upsilon(2S)$

$$\widehat{R_T} = \frac{\Gamma_{\psi(2S)\to\gamma f_2(1270)}}{\Gamma_{\psi(2S)\to\gamma f_2'(1525)}}; \quad \widehat{R_S} = \frac{\Gamma_{\psi(2S)\to\gamma f_0(1370)}}{\Gamma_{\psi(2S)\to\gamma f_0(1710)}},$$

$$\overline{R_T} = \frac{\Gamma_{\Upsilon(2S)\to\gamma f_2(1270)}}{\Gamma_{\Upsilon(2S)\to\gamma f_2'(1525)}}; \quad \overline{R_S} = \frac{\Gamma_{\Upsilon(2S)\to\gamma f_0(1370)}}{\Gamma_{\Upsilon(2S)\to\gamma f_0(1710)}}.$$

Predictions based on molecular picture

	Molecular picture
$\widehat{R_T}\ (\psi(2S))$	1.94 ± 0.97
$\widehat{R_S}\ (\psi(2S))$	1.14 ± 0.28
$\overline{R_T}\ (\Upsilon(2S))$	1.83 ± 0.92
$\overline{R_S}\ (\Upsilon(2S))$	1.05 ± 0.26

To be compared with future experiments !

Need more experimental information to further **test** on the molecular nature of these dynamically generated resonance states of $f_2(1270), f_2'(1525), f_0(1370), f_0(1710)$

4. Summary

We extend previous work of J/ψ (Hadronic and Radiative) decays $\Longrightarrow$ $\psi(nS)$ and $\Upsilon(nS)$ decays to further test on the molecular nature of $f_2(1270)$, $f_2'(1525)$,$\bar{K}_2^{*0}(1430)$ $f_0(1370)$,$f_0(1710)$ as dynamically generated states of vector meson-vector meson interaction

Results: The agreement with the data available is good

1) $\Upsilon(1S)$ into $\gamma\ f_2(1270)$ and $\gamma\ f_2'(1525)$
2) $\psi(2S)$ into $\omega\ f_2(1270)$, $\phi\ f_2'(1525)$ and $K^*(892)\ K_2^*(1430)$.

Predictions: related decays not yet available

1) $\psi(2S), \Upsilon(2S)$ into $\gamma f_2(1270)$ and $\gamma\ f_2'(1525)$;
$\psi(2S), \Upsilon(2S)$ into $\gamma f_0(1370)$ and $\gamma\ f_0(1710)$
2) $\psi(2S)$ into $\phi\ f_2(1270)$, $\omega\ f_2'(1525)$

Thank you!