Charmed baryon resonances from a unitary coupled-channel approach with heavy-quark symmetry

L. Tolós

C. Garcia-Recio, V.K. Magas, T. Mizutani, J. Nieves,

A. Ramos and L.L. Salcedo

Physical Review D 79, 054004 (2009)

- Introduction
- SU(8) extension of the WT MB lagrangian
- SU(8) results for C=1, S=0 resonances
- Comparison to SU(4) results
- Conclusions & Outlook

Introduction

- Resonance as $q\bar{q}$ / qqq or molecular state?
- Molecular state: dynamically generated via multiple scattering of their meson/baryon components $0^- + 1/2^+ \to \Lambda(1405)$

Jido, Oller, Oset, Ramos and Meissner, NPA 725 (2003) 181

- Study of resonances with charm degree of freedom motivated by experiments such as CLEO, BES, Belle and BABAR collaborations

CLEO: Artuso et al., PRL 86 (2001) 4479
BES: http://bes.ihep.ac.cn/
Belle: Mizuk et al., PRL 94 (2005) 122002; Chistov et al., PRL 97 (2006) 162001, Mizuk et al., PRL 98 (2007) 262001
BABAR: Aubert et al., PRL 97 (2006) 232001; Aubert et al., PRL 98 (2007) 012001

- From the theory side in the charm sector,
  - Extension of WT MB lagrangian using SU(4) TVME model

    Tolos, Schaffner-Bielich, Mishra, PRC 70 (2004) 025203 [SU(3)]; Hofmann and Lutz, NPA 763 (2005) 90; Hofmann and Lutz, NPA 776 (2006) 17; Mizutani and Ramos, PRC 74 (2006) 065201

  - SU(8) extension to incorporate HQS putting on equal footing 0^- and 1^- mesons, similarly to SU(6) in strange sector

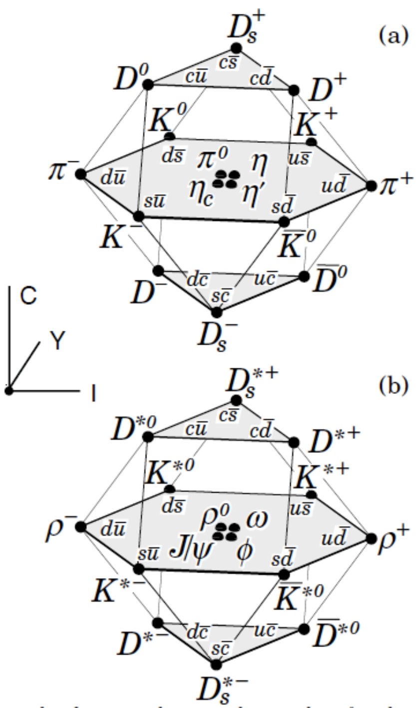
    Garcia-Recio, Nieves and Salcedo, PRD 74 (2006) 034025 [SU(6)]

SU(8) extension of the WT meson-baryon lagrangian

- In the strange sector, extension to a SU(6) model of the WT meson-baryon lagrangian Garcia-Recio, Nieves and Salcedo, PRD 74 (2006) 034025

$$(0^-,1^-)+(1/2^+,3/2^-)\rightarrow N(1535),N(1650),\Lambda(1405),\Lambda(1520),\Xi(1620)..$$

- SU(8) extension: SU(4) (flavor) ⊗ SU(2) (spin) symmetry



Mesons: $8\otimes 8^* = 63\oplus 1 = \underbrace{(15_1\oplus 15_3\oplus 1_3)}_{63}\oplus 1_1$

SU(4) n $_{2J+1}$

15_1: $(D_s, D, K, \pi, \eta, \eta_c, \bar{K}, \bar{D}, \bar{D}_s)$

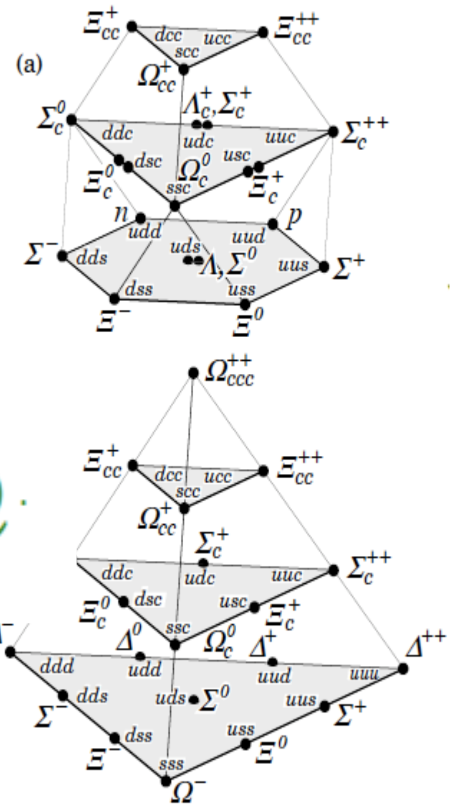
15_3: $(D_s^*, D^*, K^*, \rho, \omega, J/\Psi, \bar{K}^*, \bar{D}^*, \bar{D}_s^*, \phi)$

Baryons:

$$8\otimes 8\otimes 8 = 120\oplus 56\oplus 168\oplus 168 =$$

$$\underbrace{(20_2\oplus 20'_4)}_{120}\oplus\underbrace{(4_4\oplus 20_2)}_{56}\oplus 2\times\underbrace{(20'_2\oplus 20_4\oplus 20_2\oplus 4_2)}_{168}.$$

120: $(N,\Sigma,\Lambda,\Xi,\Delta,\Sigma^*,\Xi^*,\Omega)$
$(\Lambda_c,\ \Sigma_c,\ \Xi_c,\ \Xi'_c\ ,\Omega_c,\ \Xi_{cc},\ \Omega_{cc})$
$(\Sigma_c^*,\ \Xi_c^*,\ \Omega_c^*,\ \Omega_{cc}^*,\ \Xi_{cc}^*,\ \Omega_{ccc})$



The WT lagrangian is not only SU(3) symmetric but also chiral invariant:

$$\mathcal{L}_{\rm WT} = {\rm Tr}([M^\dagger, M][B^\dagger B]) = \Big((M^\dagger \otimes M)_{8_a} \otimes (B^\dagger \otimes B)_8\Big)_1$$

SU(8) extension of the WT lagrangian:

$$\mathbf{63} \otimes \mathbf{63} = \mathbf{1} \oplus \mathbf{63}_s \oplus \mathbf{63}_a \oplus \mathbf{720} \oplus \mathbf{945} \oplus \mathbf{945}^* \oplus \mathbf{1232}$$

$$\mathbf{120} \otimes \mathbf{120}^* = \mathbf{1} \oplus \mathbf{63} \oplus \mathbf{1232} \oplus \mathbf{13104}$$

lead to a total of 4 different *t*-channel SU(8) singlet couplings

$$\Big((M^\dagger \otimes M)_{\mathbf{1}} \otimes (B^\dagger \otimes B)_{\mathbf{1}}\Big)_{\mathbf{1}}, \qquad \Big((M^\dagger \otimes M)_{\mathbf{63}_a} \otimes (B^\dagger \otimes B)_{\mathbf{63}}\Big)_{\mathbf{1}},$$

$$\Big((M^\dagger \otimes M)_{\mathbf{63}_s} \otimes (B^\dagger \otimes B)_{\mathbf{63}}\Big)_{\mathbf{1}}, \qquad \Big((M^\dagger \otimes M)_{\mathbf{1232}} \otimes (B^\dagger \otimes B)_{\mathbf{1232}}\Big)_{\mathbf{1}}$$

To ensure that the SU(8) amplitudes will reduce to those from SU(3) WT lagrangian, we set all couplings to zero except one:

$$\mathcal{L}_{\rm WT}^{\rm SU(8)} = \Big((M^\dagger \otimes M)_{63_a} \otimes (B^\dagger \otimes B)_{63}\Big)_1$$

Then, the SU(8) WT matrix elements in *IJSC* sector are

$$V_{ab}^{IJSC}(\sqrt{s}) = D_{ab}^{IJSC}\,\frac{\sqrt{s}-M}{2\,f^2}\left(\sqrt{\frac{E+M}{2M}}\right)^2$$

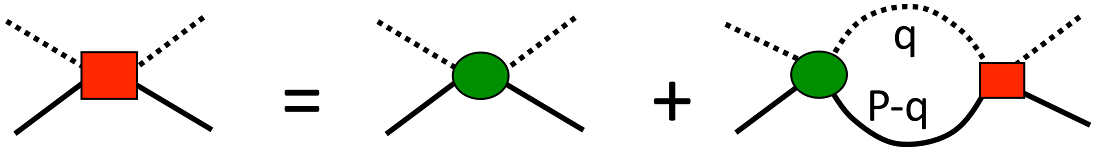
with *f* the weak decay constant and *M(E)* the mass (cm energy) of the baryons placed in the 120 SU(8) representation

However, SU(8) symmetry is strongly broken:

1. adopt physical hadron masses for kernel and thresholds
2. consider different weak non-charmed and charmed, as well as pseudoscalar and vector meson decay constants

$$V_{ab}^{IJSC}(\sqrt{s}) = D_{ab}^{IJSC}\,\frac{2\sqrt{s}-M_a-M_b}{4\,f_a f_b}\sqrt{\frac{E_a+M_a}{2M_a}}\sqrt{\frac{E_b+M_b}{2M_b}}$$

We solve the coupled-channel on-shell Bethe-Salpeter equation



$T_{ij} = V_{ij} + V_{il}\, G_l\, T_{lj}$

with

$$G_{ii}^{IJSC}(\sqrt{s}) \;=\; \mathrm{i}2M_i \int \frac{d^4q}{(2\pi)^4} \frac{1}{(P-q)^2 - M_i^2 + i\varepsilon} \frac{1}{q^2 - m_i^2 + \mathrm{i}\varepsilon}$$

which is divergent and is regularized by one-substraction at the substraction point

$$G_{ii}^{IJSC}(\sqrt{s} = \mu_i^{IJSC}) = 0$$

$$\left(\mu^{ISC}\right)^2 = \alpha\left(m_{\rm th}^2 + M_{\rm th}^2\right)$$

where m_{th}+M_{th} is the mass of the lightest hadronic channel in *ISC* sector and α is adjusted to get the Λ_c(2595) resonance

SU(8) results for C=1,S=0 resonances

The dynamically generated resonances in each *IJSC* sector are determined by

$$T_{ij}^{IJSC}(z) = \frac{g_i e^{i\phi_i} g_j e^{i\phi_j}}{(z - z_R)}$$

couplings to MB

mass and width

We examine the $\tilde{T}^{IJSC}(z) \equiv \max_j \sum_i |T_{ij}^{IJSC}(z)|$

We analize our C=1,S=0 results for J=1/2,3/2 and I=0,1, and compare to experimental data and predictions

[0]Yao et al., JPG 33 (2006) 1
[1]Mizuk et al. (Belle) PRL 94 (2005) 122002
[2]Aubert et al. (BABAR), PRL 98 (2007) 012001
[3]He, Li, Liu and Zeng, EPJC 51 (2007) 883

Yao et al., JPG 33 (2006) 1

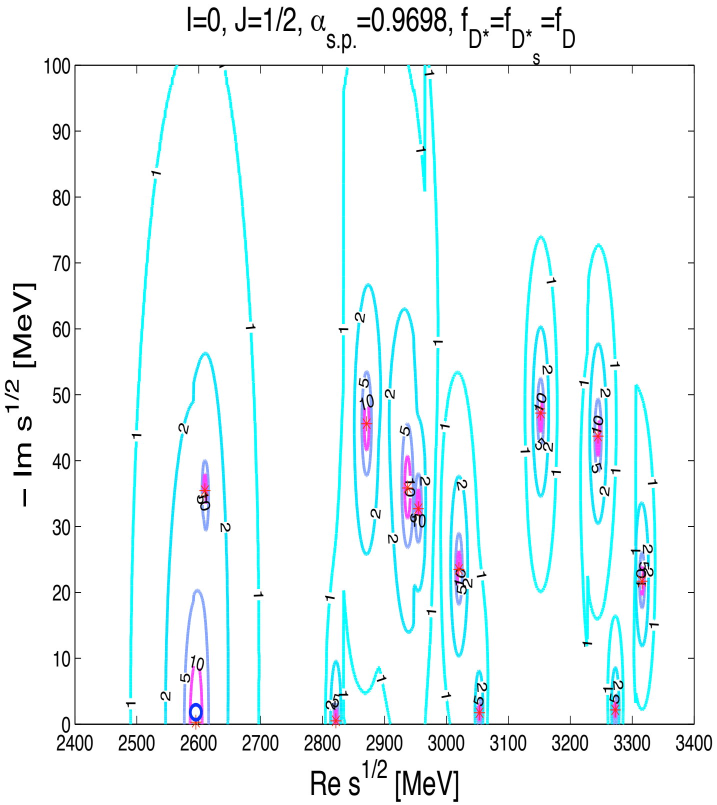
Resonance	$I(J^P)$	Status	Mass (MeV)	Γ (MeV)
$\Lambda_c(2595)$	$0(1/2^-)$	***	2595.4 ± 0.6	$3.6 + 2.0 - 1.3$
$\Lambda_c(2625)$	$0(3/2^-)$	***	2628.1 ± 0.6	<1.9
$\Lambda_c(2765)$ or $\Sigma_c(2765)$	$?(?^?)$	*	2766.6 ± 2.4	50
$\Lambda_c(2880)$	$0(5/2^+)$	***	2881.9 ± 0.5	5.8 ± 1.9
$\Lambda_c(2940)$	$0(?^?)$	***	2939.8 ± 1.6	18 ± 8
$\Sigma_c(2800)^{++}$	$1(?^?)$	***	$2801 + 4 - 6$	$75 + 22 - 17$
$\Sigma_c(2800)^{+}$	$1(?^?)$	***	$2792 + 14 - 5$	$62 + 60 - 40$
$\Sigma_c(2800)^{0}$	$1(?^?)$	***	$2802 + 4 - 7$	$61 + 28 - 18$

I=0, J=1/2

$\Sigma_c\pi$	ND	$\Lambda_c\eta$	ND^*	$\Xi_c K$	$\Lambda_c\omega$	$\Xi'_c K$	ΛD_s
2591.6	2806.15	2833.91	2947.27	2965.12	3069.03	3072.52	3084.18
ΛD^*_s	$\Sigma_c\rho$	$\Lambda_c\eta'$	$\Sigma^*_c\rho$	$\Lambda_c\phi$	$\Xi_c K^*$	$\Xi'_c K^*$	$\Xi^*_c K^*$,
3227.98	3229.05	3244.24	3293.46	3305.92	3363.33	3470.73	3540.23

$I=0, J=1/2$

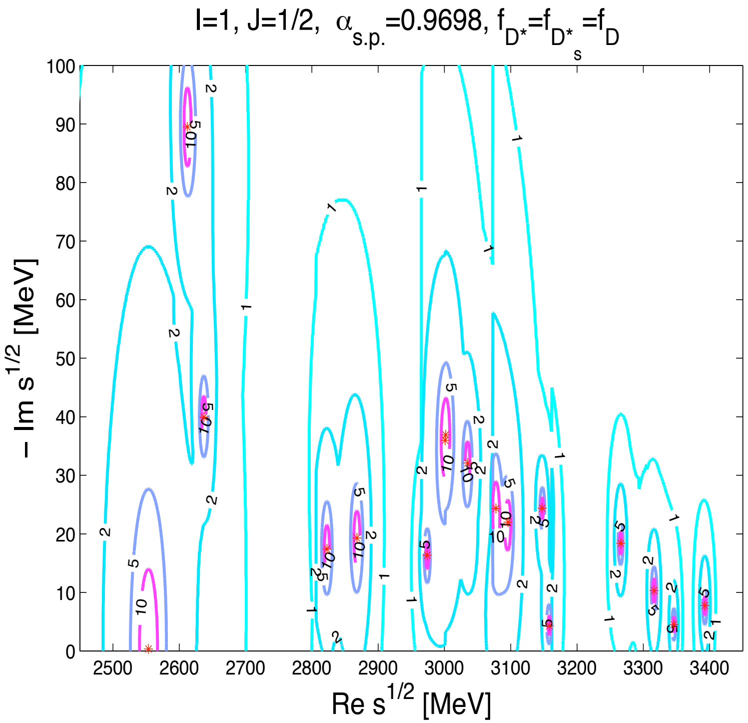
M_R	Γ_R	Couplings to main channels
2595.4	0.58	$g_{\Sigma_c\pi}=\mathbf{0.36}$, $g_{ND}=3.69$, $g_{ND^*}=5.70$, $g_{\Lambda D_s}=1.42$, $g_{\Lambda D^*_s}=2.94$
2610.0	70.9	$g_{\Sigma_c\pi}=\mathbf{2.25}$, $g_{ND}=1.47$, $g_{ND^*}=1.81$, $g_{\Sigma_c\rho}=1.22$
2821.5	1.0	$g_{ND}=\mathbf{0.32}$, $g_{\Lambda_c\eta}=1.2$, $g_{\Xi_c K}=1.79$, $g_{\Lambda D^*_s}=1.11$, $g_{\Sigma_c\rho}=1.23$, $g_{\Sigma^*_c\rho}=1.15$
2871.2	91.2	$g_{ND}=\mathbf{2.0}$, $g_{\Lambda D_s}=1.15$, $g_{ND^*}=2.15$, $g_{\Lambda D^*_s}=1.92$, $g_{\Lambda_c\omega}=1.01$, $g_{\Sigma_c\rho}=2.56$, $g_{\Sigma^*_c\rho}=0.94$
2937.2	71.7	$g_{\Lambda_c\eta}=\mathbf{1.34}$, $g_{\Lambda D_s}=1.4$, $g_{ND^*}=1.51$, $g_{\Lambda D^*_s}=3.41$, $g_{\Sigma^*_c\rho}=2.23$
2954.7	65.4	$g_{\Sigma_c\pi}=\mathbf{1.02}$, $g_{\Xi'_c K}=1.2$, $g_{\Lambda D_s}=0.85$, $g_{\Lambda_c\omega}=2.46$, $g_{\Sigma_c\rho}=1.16$, $g_{\Sigma^*_c\rho}=0.91$
3020.1	47.0	$g_{\Xi_c K}=\mathbf{1.13}$, $g_{\Lambda D_s}=1.07$, $g_{\Lambda D^*_s}=1.46$, $g_{\Sigma_c\rho}=1.51$, $g_{\Sigma^*_c\rho}=2.49$, $g_{\Xi^*_c K^*}=0.95$
3053.3	3.49	$g_{\Lambda_c\omega}=\mathbf{0.11}$, $g_{\Lambda D_s}=1.43$, $g_{\Xi'_c K}=1.49$, $g_{\Lambda_c\phi}=1.27$, $g_{\Sigma^*_c\rho}=1.02$
3152.1	94.4	$g_{\Lambda D_s}=\mathbf{1.74}$, $g_{\Lambda D^*_s}=2.02$, $g_{\Lambda_c\phi}=2.17$, $g_{\Xi'_c K^*}=0.98$, $g_{\Xi_c K^*}=1.38$, $g_{\Xi^*_c K^*}=1.16$
3244.7	87.4	$g_{\Lambda D_s}=\mathbf{0.72}$, $g_{\Lambda D^*_s}=\mathbf{0.74}$, $g_{\Xi_c K}=\mathbf{0.68}$, $g_{\Xi'_c K^*}=2.32$, $g_{\Xi^*_c K^*}=2.63$
3272.6	4.31	$g_{\Xi'_c K}=\mathbf{0.17}$, $g_{\Sigma_c\rho}=\mathbf{0.17}$, $g_{\Lambda D_s}=\mathbf{0.15}$, $g_{\Lambda_c\phi}=1.37$, $g_{\Xi_c K^*}=2.26$
3315.9	43.4	$g_{\Sigma_c\rho}=\mathbf{0.47}$, $g_{\Lambda D_s}=\mathbf{0.62}$, $g_{\Lambda_c\phi}=\mathbf{0.66}$, $g_{\Xi_c K^*}=1.2$, $g_{\Xi'_c K^*}=1.91$, $g_{\Xi^*_c K^*}=2.38$



- Λ_c(2595): Γ=0.58 MeV compared to experimental Λ_c(2595) of Γ=3.6(+2/-1.3) MeV (not included $\Lambda_c\pi\pi^0$), close to Λ_c(2610) like double pole for Λ(1405), and ND* bound state
- Λ_c(2822): Ξ_cK bound state is not Λ_c(2880) because of spin-parity, but not incompatible with pD^0 histogram[2]
- Λ_c(2938): do not correspond to Λ_c(2940) since do not couple to ND[2] or preferentially ND*[3]

$\Lambda_c\pi$	$\Sigma_c\pi$	ND	ND^*	$\Xi_c K$	$\Sigma_c\eta$	$\Lambda_c\rho$	$\Xi_c' K$	ΣD_s	ΔD^*	$\Sigma_c\rho$
2424.5	2591.6	2806.15	2947.27	2965.12	3001.01	3061.95	3072.52	3161.65	3218.35	3229.05
$\Sigma_c\omega$	$\Sigma_c^*\rho$	$\Sigma_c^*\omega$	ΣD_s^*	$\Xi_c K^*$	$\Sigma_c\eta'$	$\Xi_c' K^*$	$\Sigma_c\phi$	$\Sigma^* D_s^*$	$\Sigma_c^*\phi$	$\Xi_c^* K^*$
3236.13	3293.46	3300.54	3305.45	3363.33	3411.34	3470.73	3473.02	3496.87	3537.43	3540.23

I=1, J=1/2



$I = 1, J = 1/2$

M_R	Γ_R	Couplings to main channels
2553.6	0.67	$g_{\Lambda_c\pi} = \mathbf{0.15}$, $g_{ND} = 2.28$, $g_{\Delta D^*} = 6.74$, $g_{\Sigma^* D_s^*} = 2.89$
2612.2	179.0	$g_{\Lambda_c\pi} = \mathbf{1.95}$, $g_{ND^*} = 3.78$, $g_{\Sigma_c\rho} = 1.27$, $g_{\Sigma_c^*\rho} = 1.4$
2637.1	79.9	$g_{\Sigma_c\pi} = \mathbf{1.98}$, $g_{ND} = 2.35$, $g_{ND^*} = 1.69$, $g_{\Sigma^* D_s^*} = 1.24$
2822.8	34.8	$g_{ND} = \mathbf{1.55}$, $g_{\Sigma D_s} = 1.01$, $g_{\Xi_c K} = 1.04$, $g_{ND^*} = 1.41$, $g_{\Lambda_c\rho} = 1.37$, $g_{\Delta D^*} = 1.81$,$g_{\Sigma_c^*\rho} = 2.27$, $g_{\Xi_c^* K^*} = 0.94$
2868.0	38.6	$g_{ND} = \mathbf{0.76}$, $g_{ND^*} = 2.75$, $g_{\Sigma D_s^*} = 1.05$, $g_{\Lambda_c\rho} = 1.3$, $g_{\Sigma_c\rho} = 1.54$, $g_{\Sigma_c\omega} = 1.02$, $g_{\Delta D^*} = 1.78$
2974.0	37.2	$g_{ND} = \mathbf{0.72}$, $g_{\Sigma_c\pi} = \mathbf{0.63}$, $g_{ND^*} = \mathbf{0.63}$, $g_{\Sigma_c\eta} = 1.67$, $g_{\Lambda_c\rho} = 1.29$, $g_{\Sigma_c\omega} = 1.13$, $g_{\Delta D^*} = 1.21$
3001.9	73.8	$g_{\Xi_c K} = \mathbf{1.42}$, $g_{\Sigma D_s} = 1.68$, $g_{\Sigma D_s^*} = 4.15$, $g_{\Sigma_c\rho} = 1.42$, $g_{\Sigma_c^*\rho} = 1.26$
3034.9	64.2	$g_{\Sigma_c\pi} = \mathbf{0.72}$, $g_{\Sigma_c\eta} = \mathbf{0.67}$, $g_{ND^*} = \mathbf{0.76}$, $g_{\Sigma D_s} = 1.16$, $g_{\Sigma_c\omega} = 2.32$, $g_{\Sigma^* D_s^*} = 2.44$, $g_{\Sigma_c^*\rho} = 1.16$, $g_{\Sigma_c^*\omega} = 0.87$
3077.7	48.7	$g_{ND^*} = \mathbf{0.85}$, $g_{\Sigma_c\omega} = 2.40$, $g_{\Sigma^* D_s^*} = 3.20$, $g_{\Sigma_c^*\omega} = 1.43$
3095.9	44.0	$g_{\Lambda_c\pi} = \mathbf{0.39}$, $g_{\Xi_c' K} = \mathbf{0.88}$, $g_{ND^*} = \mathbf{0.45}$, $g_{\Sigma D_s} = 1.34$, $g_{\Sigma_c\rho} = 1.09$, $g_{\Sigma^* D_s^*} = 2.80$, $g_{\Sigma_c^*\omega} = 2.36$
3147.5	48.8	$g_{\Lambda_c\rho} = \mathbf{1.02}$, $g_{\Sigma_c\rho} = 1.62$, $g_{\Sigma_c\omega} = 0.94$, $g_{\Sigma_c^*\rho} = 1.67$, $g_{\Sigma_c^*\omega} = 1.57$
3158.2	8.6	$g_{\Sigma_c\eta} = \mathbf{0.3}$, $g_{\Lambda_c\rho} = \mathbf{0.27}$, $g_{\Sigma D_s} = 1.54$, $g_{\Sigma D_s^*} = 1.51$, $g_{\Xi_c K^*} = 1.53$
3265.8	36.8	$g_{\Sigma D_s} = \mathbf{0.69}$, $g_{\Sigma D_s^*} = 1.54$, $g_{\Sigma_c\phi} = 1.32$, $g_{\Xi_c' K^*} = 1.49$, $g_{\Sigma_c^*\phi} = 1.67$, $g_{\Xi_c^* K^*} = 1.34$
3316.2	20.6	$g_{\Xi_c' K} = \mathbf{0.44}$, $g_{\Sigma_c\phi} = 1.66$, $g_{\Xi_c' K^*} = 2.22$, $g_{\Sigma^* D_s^*} = 1.80$, $g_{\Xi_c^* K^*} = 1.01$
3346.1	9.0	$g_{\Sigma D_s} = \mathbf{0.45}$, $g_{\Sigma_c\phi} = 1.81$, $g_{\Xi_c K^*} = 1.12$, $g_{\Sigma_c^*\phi} = 1.38$, $g_{\Xi_c^* K^*} = 1.14$
3392.8	15.5	$g_{\Sigma_c^*\rho} = \mathbf{0.31}$, $g_{\Sigma_c^*\phi} = 2.17$, $g_{\Xi_c^* K^*} = 1.95$

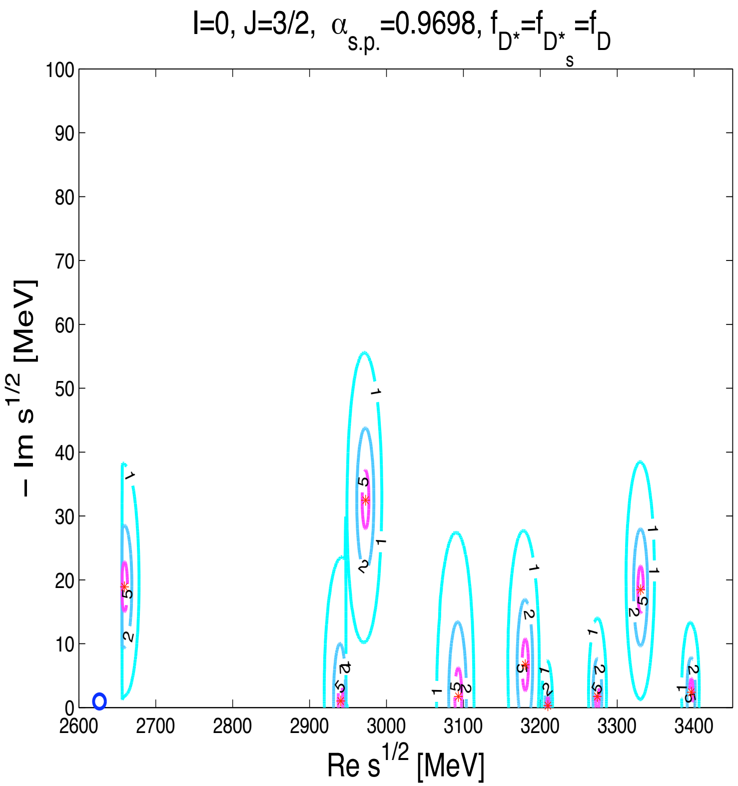
- No resonance between 2800 and 3000 MeV could correspond to $\Sigma_c(2800)$, which decays primarily in $\Lambda_c\pi$ [1]. $\Sigma_c(3096)$ is too high in mass and $\Sigma_c(3035)$, if allowed $\Lambda_c\pi\pi$ decay for $\Sigma_c(2800)$, would be too narrow if we move it to lower energies by changing the substraction point.
- Observed enhancement in I=1 D^+p histogram around 2860 MeV of width ≈ 10 MeV[2] could be our $\Sigma_c(2974)$, if it is moved to 2860 MeV since it will reduce the width

I=0, J=3/2

$\Sigma_c^*\pi$	ND^*	$\Lambda_c\omega$	Ξ_c^*K	ΛD_s^*	$\Sigma_c\rho$	$\Sigma_c^*\rho$	$\Lambda_c\phi$	$\Xi_c K^*$	$\Xi_c' K^*$	$\Xi_c^* K^*$
2656.01	2947.27	3069.03	3142.02	3227.98	3229.05	3293.46	3305.92	3363.33	3470.73	3540.23

$I = 0, J = 3/2$

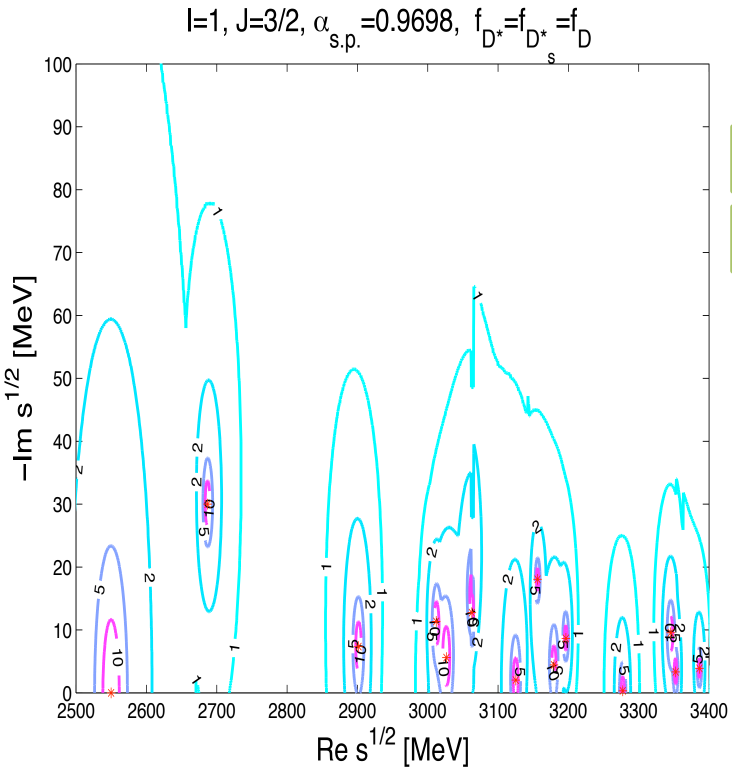
M_R	Γ_R	Couplings to main channels
2659.5	37.8	$g_{\Sigma_c^*\pi} = \mathbf{2.23}$, $g_{ND^*} = 2.11$, $g_{\Sigma_c^*\rho} = 1.34$
2940.5	2.06	$g_{\Sigma_c^*\pi} = \mathbf{0.21}$, $g_{ND^*} = 2.21$, $g_{\Sigma_c^*\rho} = 1.40$
2972.8	64.9	$g_{\Sigma_c^*\pi} = \mathbf{1.05}$, $g_{\Lambda_c\omega} = 2.42$, $g_{\Xi_c^*K} = 0.95$, $g_{\Sigma_c^*\rho} = 1.28$
3093.5	3.48	$g_{\Lambda_c\omega} = \mathbf{0.29}$, $g_{ND^*} = \mathbf{0.28}$, $g_{\Lambda D_s^*} = 2.89$, $g_{\Xi_c^*K} = 1.88$
3180.5	13.4	$g_{\Xi_c^*K} = \mathbf{0.69}$, $g_{\Lambda D_s^*} = 2.49$, $g_{\Lambda_c\phi} = 1.83$, $g_{\Xi_c K^*} = 1.00$, $g_{\Xi_c^* K^*} = 0.79$
3209.8	0.6	$g_{ND^*} = \mathbf{0.08}$, $g_{\Xi_c^*K} = \mathbf{0.10}$, $g_{\Sigma_c\rho} = 1.81$, $g_{\Sigma_c^*\rho} = 1.09$
3274.1	3.48	$g_{\Lambda D_s^*} = \mathbf{0.19}$, $g_{\Xi_c^*K} = \mathbf{0.2}$, $g_{\Lambda_c\phi} = 1.30$, $g_{\Xi_c K^*} = 2.31$
3330.4	36.9	$g_{\Lambda D_s^*} = \mathbf{0.50}$, $g_{\Lambda_c\phi} = \mathbf{0.68}$, $g_{\Sigma_c^*\rho} = \mathbf{0.57}$, $g_{\Xi_c K^*} = 0.85$, $g_{\Xi_c' K^*} = 1.85$, $g_{\Xi_c^* K^*} = 2.34$
3396.3	4.8	$g_{\Lambda D_s^*} = \mathbf{0.17}$, $g_{\Lambda_c\phi} = \mathbf{0.22}$, $g_{\Sigma_c^*\rho} = \mathbf{0.15}$, $g_{\Xi_c' K^*} = 2.17$, $g_{\Xi_c^* K^*} = 1.86$



$\Lambda_c(2660)$ with width Γ=38 MeV, which couples very strongly to $\Sigma_c^*\pi$ channel, could be $\Lambda_c(2625)$ with Γ<1.9 MeV[0] and decays mostly $\Lambda_c\pi\pi$ (counterpart of Λ(1520)). Change in the substraction point will move downward the resonance making its width much smaller because of moving below $\Sigma_c^*\pi$.

$\Sigma_c^*\pi$	ND^*	$\Lambda_c\rho$	$\Sigma_c^*\eta$	ΔD	Ξ_c^*K	ΔD^*	$\Sigma_c\rho$	$\Sigma_c\omega$	$\Sigma_c^*\rho$
2656.01	2947.27	3061.95	3065.42	3077.23	3142.02	3218.35	3229.05	3236.13	3293.46
$\Sigma_c^*\omega$	ΣD_s^*	$\Sigma^* D_s$	$\Xi_c K^*$	$\Xi_c' K^*$	$\Sigma_c\phi$	$\Sigma_c^*\eta'$	$\Sigma^* D_s^*$	$\Sigma_c^*\phi$	$\Xi_c^* K^*$
3300.54	3305.45	3353.07	3363.33	3470.73	3473.02	3475.75	3496.87	3537.43	3540.23

I=1, J=3/2



$I = 1, J = 3/2$

M_R	Γ_R	Couplings to main channels
2549.8	0.0	$g_{ND^*} = 2.52$, $g_{\Sigma D_s^*} = 2.22$, $g_{\Delta D} = 4.23$, $g_{\Sigma^* D_s} = 1.48$, $g_{\Delta D^*} = 5.28$, $g_{\Sigma^* D_s^*} = 2.29$
2686.9	60.0	$g_{\Sigma_c^*\pi} = \mathbf{1.91}$, $g_{ND^*} = 2.68$, $g_{\Sigma D_s^*} = 0.96$, $g_{\Lambda_c\rho} = 1.02$, $g_{\Sigma^* D_s^*} = 0.97$
2901.6	14.7	$g_{\Sigma_c^*\pi} = \mathbf{0.58}$, $g_{ND^*} = 2.77$, $g_{\Lambda_c\rho} = 1.52$, $g_{\Delta D} = 1.26$, $g_{\Delta D^*} = 1.05$, $g_{\Sigma_c^*\rho} = 1.20$
3012.1	22.7	$g_{ND^*} = \mathbf{0.90}$, $g_{\Sigma D_s^*} = 2.05$, $g_{\Sigma_c^*\eta} = 2.04$
3026.5	11.2	$g_{ND^*} = \mathbf{0.72}$, $g_{\Sigma_c\omega} = 2.10$, $g_{\Delta D} = 2.40$, $g_{\Delta D^*} = 2.83$
3062.6	25.5	$g_{\Sigma_c^*\eta} = \mathbf{0.61}$, $g_{\Sigma D_s^*} = 1.67$, $g_{\Delta D^*} = 1.56$, $g_{\Sigma^* D_s^*} = 1.69$, $g_{\Sigma_c^*\omega} = 1.97$
3125.1	4.05	$g_{\Sigma_c^*\pi} = \mathbf{0.17}$, $g_{\Sigma_c^*\eta} = \mathbf{0.21}$, $g_{\Sigma D_s^*} = 1.39$, $g_{\Sigma^* D_s} = 1.67$, $g_{\Xi_c^* K} = 1.33$, $g_{\Sigma^* D_s^*} = 2.90$, $g_{\Sigma_c^*\omega} = 0.93$
3156.1	36.1	$g_{\Lambda_c\rho} = \mathbf{0.9}$, $g_{\Sigma D_s^*} = 1.45$, $g_{\Sigma_c\rho} = 1.50$, $g_{\Sigma_c\omega} = 1.27$, $g_{\Sigma_c^*\rho} = 1.41$, $g_{\Sigma_c^*\omega} = 1.39$
3179.5	8.89	$g_{\Sigma_c^*\eta} = \mathbf{0.37}$, $g_{\Sigma D_s^*} = 2.65$, $g_{\Sigma_c\rho} = 1.40$, $g_{\Xi_c K^*} = 1.71$, $g_{\Sigma_c^*\omega} = 0.85$
3196.4	17.3	$g_{\Lambda_c\rho} = \mathbf{0.56}$, $g_{\Sigma D_s^*} = 0.96$, $g_{\Sigma_c\rho} = 1.17$, $g_{\Sigma_c\omega} = 0.87$, $g_{\Xi_c K^*} = 0.87$, $g_{\Sigma_c^*\rho} = 2.16$, $g_{\Sigma_c^*\omega} = 0.92$
3277.2	0.62	$g_{\Xi_c^* K} = \mathbf{0.11}$, $g_{\Sigma_c\phi} = 0.91$, $g_{\Xi_c' K^*} = 1.68$, $g_{\Sigma^* D_s} = 2.61$, $g_{\Sigma^* D_s^*} = 2.52$
3345.4	19.1	$g_{\Xi_c^* K} = \mathbf{0.54}$, $g_{\Xi_c' K^*} = 1.18$, $g_{\Sigma^* D_s^*} = 1.07$, $g_{\Sigma_c^*\phi} = 1.38$, $g_{\Xi_c^* K^*} = 2.57$
3352.6	6.65	$g_{\Sigma D_s^*} = \mathbf{0.40}$, $g_{\Xi_c^* K} = \mathbf{0.32}$, $g_{\Sigma_c\phi} = 2.26$, $g_{\Xi_c' K^*} = 1.10$, $g_{\Xi_c K^*} = 0.91$, $g_{\Sigma_c^*\phi} = 1.72$, $g_{\Xi_c^* K^*} = 0.99$
3386.3	7.79	$g_{\Xi_c K^*} = \mathbf{0.48}$, $g_{\Sigma_c\phi} = 1.40$, $g_{\Xi_c' K^*} = 1.00$, $g_{\Sigma_c^*\phi} = 2.20$, $g_{\Xi_c^* K^*} = 1.18$

- Σ_c(2550), which couples strongly to ΔD and ΔD*, could be the counterpart of the Σ(1670), which decays primarily to ΔK
- Σ_c(2901) could be the experimental Σ_c(2800) if this resonance could also be seen in $\Lambda_c\pi\pi$ states

Comparison to SU(4) results

Compared to SU(4) TVME[4-6], the SU(8) model includes vector mesons, and the transition amplitudes between states with heavy-mesons scale with the heavy-meson decay constant. We find:

✓ SU(8) model reproduces all resonances generated in SU(4) that couple strongly to 0^- meson and a charmed baryon

✓ Because of different symmetry breaking pattern, not necessarily resonances that coupled to a charmed meson and an uncharmed baryon are reproduced. Enlarged model space compensates the reduced attraction in SU(8) and generates the same resonances but with quite different composition. As example, $\Lambda_c(2595)$ (ND state)

M_R	Γ_R	Couplings to all SU(4) channels
		$I=0,\ J=1/2$
2595.4	2.01	$g_{\Sigma_c\pi}=\mathbf{0.67}$, $g_{ND}=6.03$, $g_{\Lambda_c\eta}=0.12$, $g_{\Xi_cK}=0.07$, $g_{\Xi'_cK}=0.17$, $g_{\Lambda D_s}=3.08$, $g_{\Lambda_c\eta'}=0.29$
2625.4	103.0	$g_{\Sigma_c\pi}=\mathbf{2.30}$, $g_{ND}=1.55$, $g_{\Lambda_c\eta}=0.04$, $g_{\Xi_cK}=0.03$, $g_{\Xi'_cK}=0.67$, $g_{\Lambda D_s}=1.05$, $g_{\Lambda_c\eta'}=0.1$
2799.5	0.0	$g_{\Sigma_c\pi}=\mathbf{0.35\cdot 10^{-2}}$, $g_{ND}=0.05$, $g_{\Lambda_c\eta}=1.47$, $g_{\Xi_cK}=2.57$, $g_{\Xi'_cK}=0.02$, $g_{\Lambda D_s}=0.26$, $g_{\Lambda_c\eta'}=0.02$
3024.8	31.3	$g_{\Sigma_c\pi}=\mathbf{0.59}$, $g_{ND}=\mathbf{0.50}$, $g_{\Lambda_c\eta}=\mathbf{0.16}$, $g_{\Xi_cK}=\mathbf{0.11}$, $g_{\Xi'_cK}=2.22$, $g_{\Lambda D_s}=1.48$, $g_{\Lambda_c\eta'}=0.02$

[4]Hofmann and Lutz, NPA 763 (2005) 90; 776 (2006) 17; [5]Lutz and Kolomeitsev, NPA 730 (2004) 110;
[6]Mizutani and Ramos, PRC 74 (2006) 065201

Conclusions & Outlook

•We study charmed baryon resonances within a coupled-channel unitary approach that implements heavy-quark symmetry by extending the *t*-channel vector-exchange SU(4) models to SU(8)

Yao et al., JPG 33 (2006) 1

Resonance	$I(J^P)$	Status	Mass (MeV)	Γ (MeV)
$\Lambda_c(2595)$	$0(1/2^-)$	***	2595.4 ± 0.6	$3.6 + 2.0 - 1.3$
$\Lambda_c(2625)$	$0(3/2^-)$	***	2628.1 ± 0.6	<1.9
$\Lambda_c(2765)$ or $\Sigma_c(2765)$	$?(?^?)$	*	2766.6 ± 2.4	50
$\Lambda_c(2880)$	$0(5/2^+)$	***	2881.9 ± 0.5	5.8 ± 1.9
$\Lambda_c(2940)$	$0(?^?)$	***	2939.8 ± 1.6	18 ± 8
$\Sigma_c(2800)^{++}$	$1(?^?)$	***	$2801 + 4 - 6$	$75 + 22 - 17$
$\Sigma_c(2800)^{+}$	$1(?^?)$	***	$2792 + 14 - 5$	$62 + 60 - 40$
$\Sigma_c(2800)^{0}$	$1(?^?)$	***	$2802 + 4 - 7$	$61 + 28 - 18$

$\Lambda_c(2595)$, Γ=0.58 MeV (I=0,J=1/2)

$\Lambda_c(2660)$, Γ=38 MeV (I=0,J=3/2)

$\Sigma_c(2550)$, Γ=0 MeV (I=1,J=3/2)

$\Sigma_c(2901)$, Γ=15 MeV (I=1,J=3/2) ?

•SU(8) model generates SU(4) resonances and more. However, some have different nature depending on the model, as $\Lambda_c(2595)$

•Not all SU(8) resonances are observed. Many couple weakly to the baryon-meson pairs from which are measured. A more realistic model should contain three-body channels and higher partial waves. Experiments also need more statistics