Heavy Tetraquark States and Quarkonium Hybrids

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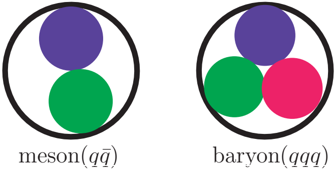
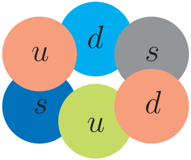
Exotic Hadrons

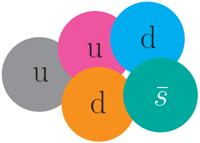


- **Quark model** is quite successful in the classification of hadrons: J^{PC} quantum numbers and flavour quantum numbers;
- However, the hadron structures are more complicated in **QCD**. It may allow for hadrons which lie outside the naive quark model;
- Mesons with exotic J^{PC} quantum numbers: $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, ...$
- Baryons with exotic flavour quantum numbers: dibaryon, pentaquark,...

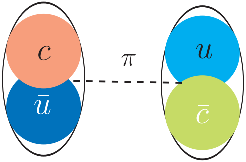
Different configurations of exotic hadron in QCD:



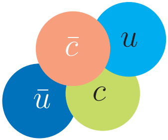
dibaryon



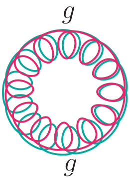
pentaquark



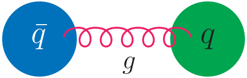
molecule



tetraquark



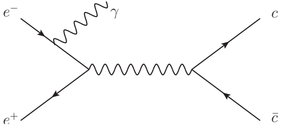
glueball



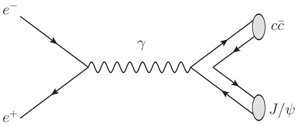
hybrid

Production mechanisms of XYZ states

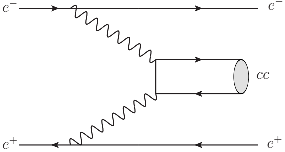
Since 2003, many new charmonium-like states are discovered experimentally:



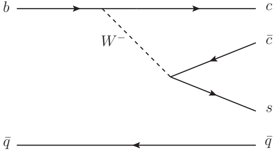
Initial State Radiation (ISR)



Double charmonium production



$\gamma\gamma$ *fusion*



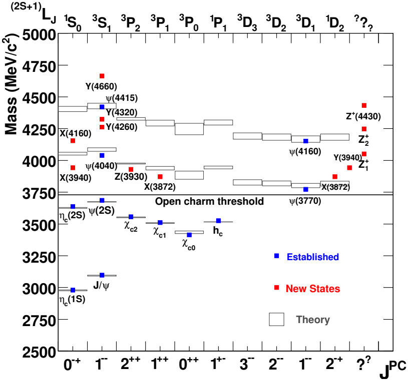
B decay

State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment (#σ)	$1^{\rm st}$ observation
$X(3823)$	3823.1 ± 1.9	< 24	$?^{?-}$	$B \to K + (\chi_{c1}\gamma)$	Belle (3.8)	Belle 2013
X**(3872)**	3871.68 ± 0.17	< 1.2	1^{++}	$B \to K + (J/\psi\,\pi^+\pi^-)$	Belle (12.8), *BABAR* (8.6)	Belle 2003
				$p\bar{p} \to (J/\psi\,\pi^+\pi^-) + \ldots$	CDF (np), DØ (5.2)	
				$B \to K + (J/\psi\,\pi^+\pi^-\pi^0)$	Belle (4.3), *BABAR* (4.0)	
				$B \to K + (D^0\bar{D}^0\pi^0)$	Belle (6.4), *BABAR* (4.9)	
				$B \to K + (J/\psi\,\gamma)$	Belle (4.0), *BABAR* (3.6)	
				$B \to K + (\psi(2S)\,\gamma)$	*BABAR* (3.5), Belle (0.4)	
				$pp \to (J/\psi\,\pi^+\pi^-) + \ldots$	LHCb	
X**(3915)**	3917.5 ± 1.9	20 ± 5	0^{++}	$B \to K + (J/\psi\,\omega)$	Belle (8.1), *BABAR* (19)	Belle 2004
				$e^+e^- \to e^+e^- + (J/\psi\,\omega)$	Belle (7.7), *BABAR* (7.6)	
$\boldsymbol{\chi_{c2}}$**(2P)**	3927.2 ± 2.6	24 ± 6	2^{++}	$e^+e^- \to e^+e^- + (D\bar{D})$	Belle (5.3), *BABAR* (5.8)	Belle 2005
$X(3940)$	3942^{+9}_{-8}	37^{+27}_{-17}	$?^{?+}$	$e^+e^- \to J/\psi + (D^*\bar{D})$	Belle (6.0)	Belle 2007
				$e^+e^- \to J/\psi + (\ldots)$	Belle (5.0)	
G**(3900)**	3943 ± 21	52 ± 11	1^{--}	$e^+e^- \to \gamma + (D\bar{D})$	*BABAR* (np), Belle (np)	*BABAR* 2007
$Y(4008)$	4008^{+121}_{-49}	226 ± 97	1^{--}	$e^+e^- \to \gamma + (J/\psi\,\pi^+\pi^-)$	Belle (7.4)	Belle 2007
Y**(4140)**	4144.5 ± 2.6	15^{+11}_{-7}	$?^{?+}$	$B \to K + (J/\psi\,\phi)$	CDF (5.0), CMS (>5)	CDF 2009
$X(4160)$	4156^{+29}_{-25}	139^{+113}_{-65}	$?^{?+}$	$e^+e^- \to J/\psi + (D^*\bar{D}^*)$	Belle (5.5)	Belle 2007

arXiv:1307.7425

State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment (#σ)	1st observation
Y(4260)	4263^{+8}_{-9}	95 ± 14	1^{--}	$e^+e^- \to \gamma + (J/\psi\, \pi^+\pi^-)$	*BABAR* (8.0), CLEO (5.4)	*BABAR* 2005
					Belle (15)	
				$e^+e^- \to (J/\psi\, \pi^+\pi^-)$	CLEO (11)	
				$e^+e^- \to (J/\psi\, \pi^0\pi^0)$	CLEO (5.1)	
Y(4274)	$4274.4^{+8.4}_{-6.7}$	32^{+22}_{-15}	$?^{?+}$	$B \to K + (J/\psi\, \phi)$	CDF (3.1)	CDF 2010
X(4350)	$4350.6^{+4.6}_{-5.1}$	$13.3^{+18.4}_{-10.0}$	$0/2^{++}$	$e^+e^- \to e^+e^-\, (J/\psi\, \phi)$	Belle (3.2)	Belle 2009
Y(4360)	4361 ± 13	74 ± 18	1^{--}	$e^+e^- \to \gamma + (\psi(2S)\, \pi^+\pi^-)$	*BABAR* (np), Belle (8.0)	*BABAR* 2007
X(4630)	4634^{+9}_{-11}	92^{+41}_{-32}	1^{--}	$e^+e^- \to \gamma\, (\Lambda_c^+\Lambda_c^-)$	Belle (8.2)	Belle 2007
Y(4660)	4664 ± 12	48 ± 15	1^{--}	$e^+e^- \to \gamma + (\psi(2S)\, \pi^+\pi^-)$	Belle (5.8)	Belle 2007
Z_c^+(3900)	3898 ± 5	51 ± 19	$1^{?-}$	$Y(4260) \to \pi^- + (J/\psi\, \pi^+)$	BESIII (np), Belle (5.2)	BESIII 2013
Z_1^+(4050)	4051^{+24}_{-43}	82^{+51}_{-55}	?	$B \to K + (\chi_{c1}(1P)\, \pi^+)$	Belle (5.0), *BABAR* (1.1)	Belle 2008
Z_2^+(4250)	4248^{+185}_{-45}	177^{+321}_{-72}	?	$B \to K + (\chi_{c1}(1P)\, \pi^+)$	Belle (5.0), *BABAR* (2.0)	Belle 2008
Z^+(4430)	4443^{+24}_{-18}	107^{+113}_{-71}	?	$B \to K + (\psi(2S)\, \pi^+)$	Belle (6.4), *BABAR* (2.4)	Belle 2007
Y_b(10888)	10888.4 ± 3.0	$30.7^{+8.9}_{-7.7}$	1^{--}	$e^+e^- \to (\Upsilon(nS)\, \pi^+\pi^-)$	Belle (2.0)	Belle 2010
Z_b^+(10610)	10607.2 ± 2.0	18.4 ± 2.4	1^{+-}	$\Upsilon(5S) \to \pi^- + (\Upsilon/h_b\, \pi^+)$,	Belle (16)	Belle 2011
Z_b^+(10650)	10652.2 ± 1.5	11.5 ± 2.2	1^{+-}	$\Upsilon(5S) \to \pi^- + (\Upsilon/h_b\, \pi^+)$,	Belle (16)	Belle 2011

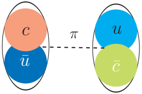
Charmonium Spectum



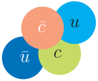
- They contain a $c\bar{c}$ pair and are above the $D\bar{D}$ threshold;
- Some are very narrow or even charged;
- Absence of the open-charm decay channels;
- Their masses are not compatible with the prediction for $c\bar{c}$ states;
- They are good candidates for exotic mesons!

Possible Interpretations

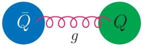
Molecule: loosely bound states composed of a pair of mesons, probably bound by the long-rang color-singlet pion exchange



Tetraquark: bound states of four quarks, bound by colored-force between quarks, decay through rearrangement, some are charged



Hybrid: composed of a pair of quarks and one excited gluonic field



In this talk, I will focus on the tetraquark states and quarkonium hybrids.

QCD Sum Rule

Two-point correlation function:

$$\Pi_{\mu\nu}(q^2) = i\int d^4x e^{iq\cdot x}\langle 0|T[J_\mu(x)J_\nu^\dagger(0)]|0\rangle,$$

- Hadron level: described by the dispersion relation

$$\begin{aligned}\Pi(q^2) &= \frac{(q^2)^N}{\pi}\int\frac{\text{Im}\Pi(s)}{s^N(s-q^2-i\epsilon)}ds+\sum_{n=0}^{N-1}b_n(q^2)^n,\\ \rho(s) &= \frac{1}{\pi}\text{Im}\Pi(s)=\sum_n\delta(s-m_n^2)\langle 0|J|n\rangle\langle n|J^\dagger|0\rangle\\ &\qquad\qquad = f_X^2\delta(s-m_X^2)+\text{continuum},\end{aligned}$$

- Borel transform:

$$\Pi(M_B^2)=\int_0^\infty ds\rho(s)e^{-s/M_B^2},$$

QCD Sum Rule

- Quark-gluon level: evaluated via operator product expansion(OPE)

$$\rho(s) = \rho^{pert}(s) + \rho^{\langle\bar{q}q\rangle}(s) + \rho^{\langle GG\rangle}(s) + \rho^{\langle\bar{q}q\rangle^2}(s) + \rho^{\langle\bar{q}Gq\rangle}(s) + \ldots,$$

- Sum rules: quark-hadron duality

$$\mathcal{L}_k\left(s_0, M_B^2\right) = \int_{4m_Q^2}^{s_0} ds e^{-s/M_B^2}\rho(s)s^k = f_X^2 m_X^{2k} e^{-m_X^2/M_B^2},$$

- Hadron mass:

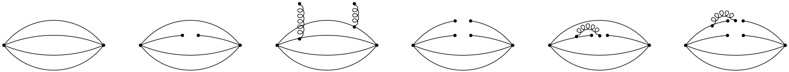
$$m_X\left(s_0, M_B^2\right) = \sqrt{\frac{\mathcal{L}_1\left(s_0, M_B^2\right)}{\mathcal{L}_0\left(s_0, M_B^2\right)}}.$$

We use this equation to predict the hadron mass in our analysis!

Tetraquark Sum Rule Analysis

Spectral density $\rho(s)$ at the quark-gluon level:

$$\rho(s) = \rho^{pert}(s) + \rho^{\langle\bar{q}q\rangle}(s) + \rho^{\langle GG\rangle}(s) + \rho^{\langle\bar{q}q\rangle^2}(s) + \rho^{\langle\bar{q}Gq\rangle}(s),$$

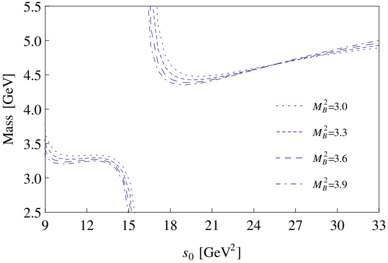


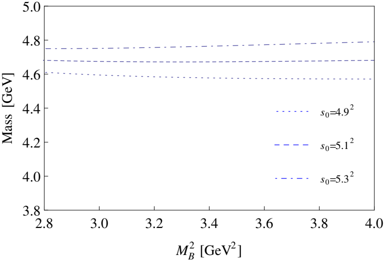
Tetraquark mass:

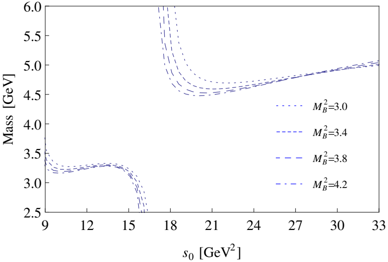
$$m_X\left(s_0, M_B^2\right) = \sqrt{\frac{\mathcal{L}_1\left(s_0, M_B^2\right)}{\mathcal{L}_0\left(s_0, M_B^2\right)}},$$

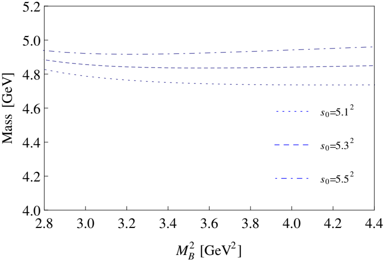
- We first fix the value of threshold parameter s_0;
- A Borel window is obtained by studying the pole contribution and OPE convergence;
- Stabilities of the mass sum rules are also required.

For $qc\bar{q}\bar{c}$ and $sc\bar{s}\bar{c}$ systems with $J^{PC} = 1^{-+}$









For $qc\bar{q}\bar{c}$ and $sc\bar{s}\bar{c}$ systems with $J^{PC} = 1^{--}$

Phys. Rev. D83, 034010 (2011)

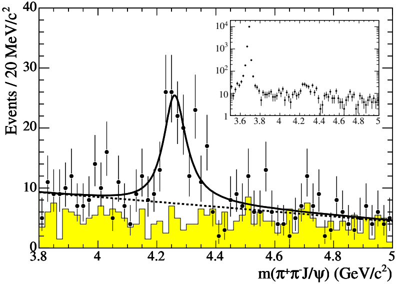
	Currents	$s_0(\text{GeV}^2)$	$[M^2_{\text{min}}, M^2_{\text{max}}](\text{GeV}^2)$	$m_X(\text{GeV})$	PC(%)
$qc\bar{q}\bar{c}$ system	$J_{1\mu}$	5.0^2	$2.9 \sim 3.6$	4.64 ± 0.09	44.1
	$J_{4\mu}$	5.0^2	$2.9 \sim 3.6$	4.61 ± 0.10	46.4
	$J_{7\mu}$	5.2^2	$2.9 \sim 4.1$	4.74 ± 0.10	47.3
$sc\bar{s}\bar{c}$ system	$J_{1\mu}$	5.4^2	$2.8 \sim 4.5$	4.92 ± 0.10	50.3
	$J_{2\mu}$	5.0^2	$2.8 \sim 3.5$	4.64 ± 0.09	48.6
	$J_{3\mu}$	4.9^2	$2.8 \sim 3.4$	4.52 ± 0.10	45.6
	$J_{4\mu}$	5.4^2	$2.8 \sim 4.5$	4.88 ± 0.10	51.7
	$J_{7\mu}$	5.3^2	$2.8 \sim 4.3$	4.86 ± 0.10	46.0
	$J_{8\mu}$	4.8^2	$2.8 \sim 3.1$	4.48 ± 0.10	43.2

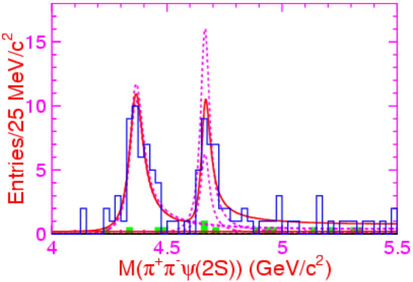
The masses for $qc\bar{q}\bar{c}$ states are around 4.6 – 4.7 GeV.

$Y(J^{PC} = 1^{--})$ family

Since 2005, *BABAR* and Belle discovered $Y(4260)$, $Y(4360)$ and $Y(4660)$ in the ISR process:

- $Y(4260)$: $e^+e^- \to \gamma_{ISR} J/\psi\pi^+\pi^-$, PRL95, 142001(2005)
- $Y(4360)$, $Y(4660)$: $e^+e^- \to \gamma_{ISR}\psi(2S)\pi^+\pi^-$, PRL99, 142002(2007)
- $Y(4660)$: $m = 4664 \pm 11 \pm 5$ MeV, $\Gamma = 48 \pm 15 \pm 3$ MeV





Our result supports $Y(4660)$ as a $qc\bar{q}\bar{c}$ tetraquark state!

For $qc\bar{q}\bar{c}$, $sc\bar{s}\bar{c}$, $qb\bar{q}\bar{b}$ and $sb\bar{s}\bar{b}$ systems with $J^{PC}=1^{++}$

Phys. Rev. D83, 034010 (2011)

	Currents	s_0(GeV^2)	[M^2_{min},M^2_{max}](GeV^2)	m_X(GeV)	PC(%)
$qc\bar{q}\bar{c}$ system	$J_{3\mu}$	4.6^2	$3.0\sim3.4$	4.19 ± 0.10	47.3
	$J_{4\mu}$	4.5^2	$3.0\sim3.3$	4.03 ± 0.11	46.8
$sc\bar{s}\bar{c}$ system	$J_{3\mu}$	4.6^2	$3.0\sim3.4$	4.22 ± 0.10	45.7
	$J_{4\mu}$	4.5^2	$3.0\sim3.3$	4.07 ± 0.10	44.4
$qb\bar{q}\bar{b}$ system	$J_{3\mu}$	10.9^2	$8.5\sim9.5$	10.32 ± 0.09	47.0
	$J_{4\mu}$	10.8^2	$8.5\sim9.2$	10.22 ± 0.11	44.6
	$J_{7\mu}$	10.7^2	$7.8\sim8.4$	10.14 ± 0.10	44.8
	$J_{8\mu}$	10.7^2	$7.8\sim8.4$	10.14 ± 0.09	44.8
$sb\bar{s}\bar{b}$ system	$J_{3\mu}$	10.9^2	$8.5\sim9.5$	10.34 ± 0.09	46.1
	$J_{4\mu}$	10.8^2	$8.5\sim9.1$	10.25 ± 0.10	43.3
	$J_{7\mu}$	10.8^2	$7.5\sim8.6$	10.24 ± 0.11	47.1
	$J_{8\mu}$	10.8^2	$7.5\sim8.6$	10.24 ± 0.10	47.1

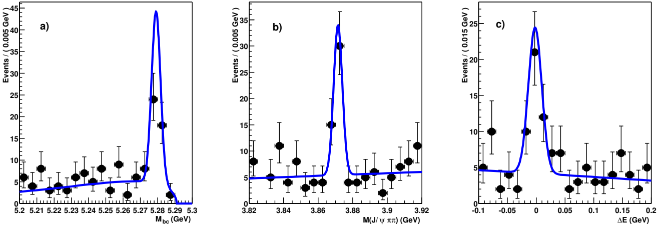
The extracted mass 4.0 GeV is slightly above the mass of $X(3872)$.

First New State: $X(3872)$

- In 2003, Belle discovered $X(3872)$ in $B^+ \to K^+ J/\psi\pi^+\pi^-$ with

$$m = 3872.0 \pm 0.6 \pm 0.5\text{MeV}, \quad \Gamma < 2.3\text{MeV},$$ PRL91, 262001(2003)

- In 2013, LHCb (PRL110, 222001(2013)) determined the quantum numbers of $X(3872)$: $J^{PC} = 1^{++}$



Our results don't preclude the tetraquark interpretation of $X(3872)$.

For $qc\bar{q}\bar{c}$, $sc\bar{s}\bar{c}$, $qb\bar{q}\bar{b}$ and $sb\bar{s}\bar{b}$ systems with $J^{PC}=1^{+-}$

Phys. Rev. D83, 034010 (2011)

	Currents	$s_0(\text{GeV}^2)$	$[M^2_{\text{min}}, M^2_{\text{max}}](\text{GeV}^2)$	$m_X(\text{GeV})$	PC(%)
$qc\bar{q}\bar{c}$ system	$J_{3\mu}$	4.6^2	$3.0-3.4$	4.16 ± 0.10	46.2
	$J_{4\mu}$	4.5^2	$3.0-3.3$	4.02 ± 0.09	44.6
	$J_{5\mu}$	4.5^2	$3.0-3.4$	4.00 ± 0.11	46.0
	$J_{6\mu}$	4.6^2	$3.0-3.4$	4.14 ± 0.09	47.0
$sc\bar{s}\bar{c}$ system	$J_{3\mu}$	4.7^2	$3.0-3.6$	4.24 ± 0.10	49.6
	$J_{4\mu}$	4.6^2	$3.0-3.5$	4.12 ± 0.11	47.3
	$J_{5\mu}$	4.5^2	$3.0-3.3$	4.03 ± 0.11	44.2
	$J_{6\mu}$	4.6^2	$3.0-3.4$	4.16 ± 0.11	46.0
$qb\bar{q}\bar{b}$ system	$J_{3\mu}$	10.6^2	$7.5-8.5$	10.08 ± 0.10	45.9
	$J_{4\mu}$	10.6^2	$7.5-8.5$	10.07 ± 0.10	46.2
	$J_{5\mu}$	10.6^2	$7.5-8.4$	10.05 ± 0.10	45.3
	$J_{6\mu}$	10.7^2	$7.5-8.7$	10.15 ± 0.10	47.6
$sb\bar{s}\bar{b}$ system	$J_{3\mu}$	10.6^2	$7.5-8.3$	10.11 ± 0.10	43.8
	$J_{4\mu}$	10.6^2	$7.5-8.4$	10.10 ± 0.10	44.1
	$J_{5\mu}$	10.6^2	$7.5-8.3$	10.08 ± 0.10	43.7
	$J_{6\mu}$	10.7^2	$7.5-8.5$	10.18 ± 0.10	46.5

In 2013, BESIII discovered two charged states $Z_c(3900)$ and $Z_c(4025)$:

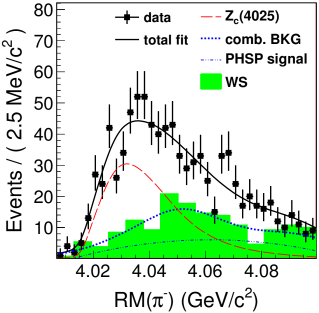
- $Z_c(3900)$: $e^+e^- \to \pi^+\pi^- J/\psi$, (PRL110, 252001(2013))

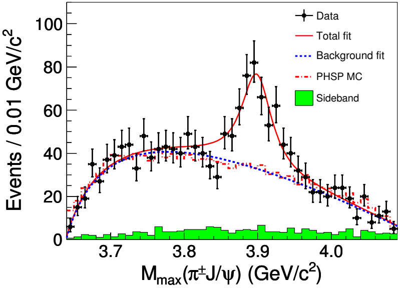
$$m = 3899.0 \pm 3.6 \pm 4.9\text{MeV}, \Gamma = 46 \pm 10 \pm 20\text{MeV}$$

- $Z_c(4025)$: $e^+e^- \to (D^*\bar{D}^*)^{\pm}\pi^{\mp}$, (PRL112, 132001(2014))

$$m = 4026.3 \pm 2.6 \pm 3.7\text{MeV}, \Gamma = 24.8 \pm 5.6 \pm 7.7\text{MeV}$$

They prefer $J^{PC} = 1^{+-}$





Our result supports $Z_c(3900)$ and $Z_c(4025)$ as $qc\bar{q}\bar{c}$ tetraquark states!

Hybrid Sum Rules

Two-point Correlation Function:

$$\Pi_{\mu\nu}(q^2) = i \int d^4x e^{iq\cdot x} \langle 0| T[J_\mu(x) J_\nu^\dagger(0)] |0\rangle,$$

where $J_\mu(x)$ is the hybrid interpolating currents

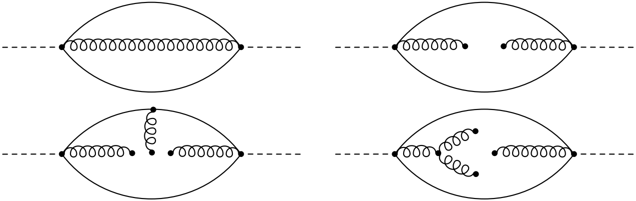
$$\begin{aligned}
J_\mu &= g_s \bar{Q} \frac{\lambda^a}{2} \gamma^\nu G^a_{\mu\nu} Q, & J^{PC} &= 1^{-+}, 0^{++}, \\
J_\mu &= g_s \bar{Q} \frac{\lambda^a}{2} \gamma^\nu \gamma_5 G^a_{\mu\nu} Q, & J^{PC} &= 1^{+-}, 0^{--}, \\
J_{\mu\nu} &= g_s \bar{Q} \frac{\lambda^a}{2} \sigma^\alpha_\mu \gamma_5 G^a_{\alpha\nu} Q, & J^{PC} &= 2^{-+}, 1^{++}, 1^{-+}, 0^{-+},
\end{aligned}$$

By replacing $G^a_{\mu\nu}$ with $\tilde{G}^a_{\mu\nu} = \frac{1}{2}\epsilon_{\mu\nu\alpha\beta} G^{\alpha\beta,a}$, we obtain the corresponding $\tilde{J}_\mu$ and $\tilde{J}_{\mu\nu}$ with opposite parities.

Sum Rule Analysis

- Quark-gluon level: $\rho(s)$ is calculated up to dimension six:

$$\rho(s) = \rho^{pert}(s) + \rho^{\langle GG\rangle}(s) + \rho^{\langle GGG\rangle} + \rho^{\langle jj\rangle},$$



- Fix on the value of threshold value s_0
- Determine the Borel window by studying OPE convergence and PC
- The Borel curves should be stable

Spectrum for $\bar{c}Gc$ charmonium hybrids

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J^{PC}	$s_0(\mathrm{GeV}^2)$	$[M^2_{\min}, M^2_{\max}](\mathrm{GeV}^2)$	$m_X(\mathrm{GeV})$	PC(%)
1^{--}	15	$2.5 \sim 4.8$	3.36 ± 0.15	18.3
0^{-+}	16	$5.6 \sim 7.0$	3.61 ± 0.21	15.4
1^{-+}	17	$4.6 \sim 6.5$	3.70 ± 0.21	18.8
2^{-+}	18	$3.9 \sim 7.2$	4.04 ± 0.23	26.0
0^{+-}	20	$6.0 \sim 7.4$	4.09 ± 0.23	15.5
2^{++}	23	$3.9 \sim 7.5$	4.45 ± 0.27	21.5
1^{+-}	24	$2.5 \sim 8.4$	4.53 ± 0.23	33.2
1^{++}	30	$4.6 \sim 11.4$	5.06 ± 0.44	30.4
0^{++}	34	$5.6 \sim 14.6$	5.34 ± 0.45	36.3
0^{--}	35	$6.0 \sim 12.3$	5.51 ± 0.50	31.0

- Unstable channels are stabilized and the mass predictions are reliable!
- 1^{++} charmonium hybrid is much heavier than $X(3872)$ while 1^{--} hybrid is lighter than $Y(4260)$, which seem to preclude a pure hybrid interpretation for these states.

Spectrum for $\bar{b}Gb$ bottomonium hybrids

JHEP09(2013)019

J^{PC}	$s_0(\text{GeV}^2)$	$[M^2_{\text{min}}, M^2_{\text{max}}](\text{GeV}^2)$	$m_X(\text{GeV})$	PC(%)
1^{--}	105	$11 \sim 17$	9.70 ± 0.12	17.2
0^{-+}	104	$14 \sim 16$	9.68 ± 0.29	17.3
1^{-+}	107	$13 \sim 19$	9.79 ± 0.22	20.4
2^{-+}	105	$12 \sim 19$	9.93 ± 0.21	21.7
0^{+-}	114	$14 \sim 19$	10.17 ± 0.22	17.6
2^{++}	120	$12 \sim 20$	10.64 ± 0.33	19.7
1^{+-}	123	$10 \sim 21$	10.70 ± 0.53	28.5
1^{++}	134	$13 \sim 27$	11.09 ± 0.60	27.7
0^{++}	137	$13 \sim 31$	11.20 ± 0.48	30.0
0^{--}	142	$14 \sim 25$	11.48 ± 0.75	24.1

We have confirmed the hybrid supermultiplet structure:

- Lightest hybrid supermultiplet: negative-parity states with $J^{PC} = 1^{--}, (0,1,2)^{-+}$;
- Heavier hybrid supermultiplet: positive-parity states with $J^{PC} = (0,1)^{+-}, (0,1,2)^{++}$;
- Heaviest 0^{--} hybrid may suggest a highly excited gluonic structure.

Summary

Spectra of the quarkonium-like tetraquark states

- Construct all tetraquark interpolating currents in a systematic way;
- Calculate the two-point correlation functions;
- Obtain the spectra of $qc\bar{q}\bar{c}$ and $qb\bar{q}\bar{b}$ tetraquark states in QSR;
- Support the $qc\bar{q}\bar{c}$ tetraquark interpretation of $Y(4660)$;
- Don't preclude the tetraquark interpretation of $X(3872)$;
- Support $Z_c(3900)$, $Z_c(4025)$ states to be 1^{+-} $qc\bar{q}\bar{c}$ tetraquark states.

Spectra of the quarkonium hybrids

- Unstable channels are stabilized by the dimension six condensates;
- Predict the masses of the exotic hybrid channels: $1^{-+}, 0^{+-}, 0^{--}$;
- Preclude the pure hybrid interpretations of $X(3872)$ and $Y(4260)$;
- Confirm the supermultiplet structures of the hybrid spectrum.

THANK YOU VERY MUCH!