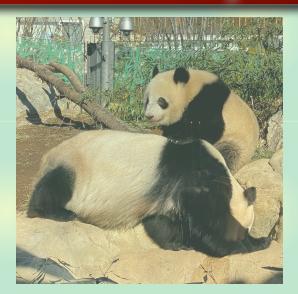
# Compositeness of hadrons and its application to baryon resonances





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## **Compositeness with weak-binding relation**

S. Weinberg, Phys. Rev. 137, B672 (1965); <u>T. Hyodo, Int. J. Mod. Phys. A 28, 1330045 (2013);</u> <u>Y. Kamiya, T. Hyodo, PRC93, 035203 (2016); PTEP2017, 023D02 (2017)</u> <u>T. Kinugawa, T. Hyodo, PRC106, 015205 (2022)</u>

## **Compositeness of baryon resonances**

T. Sekihara, T. Hyodo, D. Jido, PTEP2015, 063D04 (2015); T. Sekihara, T. Arai, J. Yamagata-Sekihara, S. Yasui, PRC93, 035204 (2016)



## **Observed hadrons (2020)**

### Particle Data Group (PDG) 2020 eddition

http://pdg.lbl.gov/

р	1/2+ *	***	<i>∆</i> (1232)	3/2+ ****	$\Sigma^+$	1/2+	****	<u>=</u> 0	1/2+	****	$\Xi_{cc}^{++}$		***
n		***	$\Delta(1600)$	3/2+ ****	$\Sigma^0$	$1/2^+$	****	<u> </u>	$1/2^{+}$	****	cc		
N(1440)	1/2+ *	***	$\Delta(1620)$	1/2- ****	$\Sigma^{-}$	$1/2^{+}$	****	$\Xi(1530)$	3/2+	****	$\Lambda_b^0$	$1/2^{+}$	***
N(1520)	3/2- *	***	$\Delta(1700)$	3/2- ****	Σ(1385)	3/2+	****	$\Xi(1620)$		*	$\Lambda_{b}(5912)^{0}$	$1/2^{-}$	***
N(1535)	1/2- *	***	$\Delta(1750)$	1/2+ *	Σ(1580)	3/2-	*	$\Xi(1690)$		***	$\Lambda_b(5920)^0$	$3/2^{-}$	***
N(1650)	1/2- *	***	<i>∆</i> (1900)	1/2- ***	Σ(1620)	$1/2^{-}$	*	$\Xi(1820)$	$3/2^{-}$	***	$\Lambda_b(6146)^0$	3/2+	***
N(1675)	0,2	***	$\Delta(1905)$	5/2+ ****	$\Sigma(1660)$	$1/2^{+}$		$\Xi(1950)$		***	$\Lambda_b(6152)^0$	5/2+	***
N(1680)	0/2	***	<i>∆</i> (1910)	1/2+ ****	Σ(1670)	3/2-	****	Ξ(2030)	$\geq \frac{5}{2}$ ?	***	$\Sigma_b$	$1/2^{+}$	***
N(1700)	○/ = .	**	$\Delta(1920)$	3/2+ ***	$\Sigma(1750)$	$1/2^{-}$	***	$\Xi(2120)$		*	$\Sigma_b^*$	3/2+	***
N(1710)	-/ -	***	$\Delta(1930)$	5/2- ***	$\Sigma(1775)$	5/2-	****	Ξ(2250)		**	$\Sigma_{b}(6097)^{+}$		***
N(1720)	5/2	***	<i>∆</i> (1940)	3/2 **	$\Sigma(1780)$	3/2+	*	$\Xi(2370)$		**	$\Sigma_{b}(6097)^{-}$		***
N(1860)	5/2	*	$\Delta(1950)$	7/2+ ****	$\Sigma(1880)$	1/2+	**	$\Xi(2500)$		*	$\Xi_{b}^{0}, \Xi_{b}^{-}$	$1/2^+$	***
N(1875)	5/2	**	$\Delta(2000)$	5/2 <sup>+</sup> ** 1/2 <sup>-</sup> *	$\Sigma(1900)$	1/2-	**		a /a±	****	$\Xi_{b}^{\prime}(5935)^{-}$	$1/2^{+}$	***
N(1880)		**	$\Delta(2150)$	1/2	$\Sigma(1910)$	3/2-	***	$\Omega^{-}$	3/2+		$\Xi_b(5945)^0$	3/2+	***
N(1895)	-/	*** ***	$\Delta(2200)$	7/2 <sup>-</sup> *** 9/2 <sup>+</sup> **	$\Sigma(1915)$	5/2+	****	$\Omega(2012)^{-}$	?-	*** ***	$\Xi_b(5955)^-$	3/2+	***
N(1900)	-/-	****	$\Delta(2300)$	-/ -	$\Sigma(1940)$	3/2+	*	$\Omega(2250)^{-}$		**	$\Xi_{b}(6227)$		***
N(1990)	• / = .	-* -*	$\Delta(2350)$	o/	$\Sigma(2010)$	3/2- 7/2+	****	$\Omega(2380)^{-}$		**	$\Omega_b^-$	$1/2^{+}$	***
N(2000)	3/2+ *		⊿(2390) ⊿(2400)	7/2 <sup>+</sup> * 9/2 <sup>-</sup> **	$\Sigma(2030)$	$5/2^+$	*	$\Omega(2470)^{-}$			D (4210)+		*
N(2040) N(2060)		**	$\Delta(2400)$ $\Delta(2420)$	9/2 11/2 <sup>+</sup> ****	$\Sigma(2070)$ $\Sigma(2080)$	$3/2^+$	*	$\Lambda_c^+$	$1/2^{+}$	****	$P_{c}(4312)^{+}$ $P_{c}(4380)^{+}$		*
N(2000) N(2100)		**	$\Delta(2420)$ $\Delta(2750)$	13/2 **	$\Sigma(2000)$ $\Sigma(2100)$	7/2-	*	$\Lambda_{c}(2595)^{+}$		***	$P_c(4300)^+$ $P_c(4440)^+$		*
N(2100) N(2120)	-/-	**	$\Delta(2750)$ $\Delta(2950)$	15/2 <sup>+</sup> **	$\Sigma(2100)$ $\Sigma(2160)$	$1/2^{-}$	*	$\Lambda_c(2625)^+$	3/2-	***	$P_c(4440)^+$ $P_c(4457)^+$		*
N(2120) N(2190)	0/2	***	д(2,50)	15/2	$\Sigma(2230)$	$3/2^+$	*	$\Lambda_{c}(2765)^{+}$	5/2	*	F <sub>C</sub> (4431)		
N(2220)	•/~	***	Λ	1/2+ ****	$\Sigma(2250)$	5/2	***	$\Lambda_c(2860)^+$	3/2+	***			
N(2250)	-/-	***	Λ	1/2 **	$\Sigma(2455)$		**	$\Lambda_{c}(2880)^{+}$		***			
N(2300)	1/2+ *	*	A(1405)	1/2- ****	$\Sigma(2620)$		**	$\Lambda_{c}(2940)^{+}$	3/2-	***			
N(2570)	5/2- *	*	A(1520)	3/2- ****	Σ(3000)		*	$\Sigma_{c}(2455)$	$1/2^{+}$	****			
N(2600)	11/2-*	**	A(1600)	1/2+ ****	Σ(3170)		*	$\Sigma_c(2520)$	3/2+	***			
N(2700)	13/2+ *		A(1670)	1/2- ****	. ,			$\Sigma_c(2800)$	·	***			
. ,	,		A(1690)	3/2- ****					$1/2^{+}$	***			
			A(1710)	1/2+ *				=+ = c = c = c = c + = c c = c c = c c = c c	$1/2^{+}$	****			
			A(1800)	1/2 ***				$\Xi_{c}^{+}$	$1/2^{+}$	***			
			<i>N</i> (1810)	1/2+ ***				<u>=</u> <sup>0</sup>	$1/2^{+}$	***			
			A(1820)	5/2+ ****				$\Xi_{c}(2645)$	3/2+	***			
			A(1830)	5/2- ****				$\Xi_{c}(2790)$	$1/2^{-}$	***			
			A(1890)	3/2+ ****				$\Xi_{c}(2815)$	3/2-	*		_	
			A(2000)	1/2- *				$\Xi_{c}(2930)$					
			A(2050)	3/2 *				$\Xi_{c}(2970)$					
			A(2070)	3/2+ *				$\Xi_{c}(3055)$					
			A(2080)	5/2 <sup>-</sup> *				$\Xi_{c}(3080)$					
			A(2085)	7/2 <sup>+</sup> ** 7/2 <sup>-</sup> ****				$\Xi_{c}(3123)$		*		/	
			A(2100)	1/2				$\Omega_c^0$	$1/2^{+}$	***			
			A(2110)	5/2 <sup>+</sup> *** 3/2 <sup>-</sup> *				0,022000	2 /0+	***			
			A(2325)	3/2 9/2 <sup>+</sup> ***			-	-					
			A(2350) A(2585)	9/2 **		_1	6	nk	12	K1	IN	חכ	
			(2000)		· ·		U	0 k	Ja		γυι		
								14c(3120)~					

LIGHT UNFLAVORED ( $S = C = B = 0$ )		STRAN ( $S = \pm 1, C$		CHARMED, (C = S)		<i>c</i> ₹ con	tinued $F(\mathcal{P}^{C})$		
	$P(J^{PC})$		$P(\mathcal{P}^{\mathcal{C}})$	(3 - 11, 0	()P)	(0 - 3	(P)		
+		(4.5-0)	. ,	1.ct		<b>D</b> <sup>+</sup>		<ul> <li>ψ(3770)</li> <li>(2000)</li> </ul>	0-(1
• π <sup>±</sup>	$1^{-}(0^{-})$	<ul> <li>π<sub>2</sub>(1670)</li> </ul>	$1^{-}(2^{-+})$	• K <sup>±</sup>	1/2(0-)	• D <sup>±</sup> 5	0(0 <sup>-</sup> )	<ul> <li>ψ<sub>2</sub>(3823)</li> </ul>	0-(2
• $\pi^{0}$	$1^{-}(0^{-+})$	<ul> <li>         \$\phi(1680)\$     </li> </ul>	0-(1)	• K <sup>0</sup>	1/2(0-)	<ul> <li>D<sup>*±</sup></li> <li>S</li> </ul>	0(??)	<ul> <li>ψ<sub>3</sub>(3842)</li> </ul>	0-(3
• η	$0^{+}(0^{-+})$	<ul> <li> <i>ρ</i><sub>3</sub>(1690)     </li> </ul>	1+(3)	• K <sup>0</sup> <sub>S</sub>	1/2(0-)	• $D_{s0}^*(2317)^{\pm}$		$\chi_{c0}(3860)$	$0^{+}(0^{++})$
• f <sub>0</sub> (500)	0+(0++)	<ul> <li>ρ(1700)</li> </ul>	1+(1)	• K2	$1/2(0^{-})$	<ul> <li>D<sub>51</sub>(2460)<sup>±</sup></li> </ul>		• χ <sub>c1</sub> (3872)	0+(1++
<ul> <li>ρ(770)</li> </ul>	1+(1)	• $a_2(1700)$	1-(2++)	<ul> <li>K<sup>*</sup><sub>0</sub>(700)</li> </ul>	$1/2(0^+)$	<ul> <li>D<sub>51</sub>(2536)<sup>±</sup></li> </ul>		• Z <sub>c</sub> (3900)	1+(1+-
• ω(782)	$0^{-}(1^{-})$	• f <sub>0</sub> (1710)	0+(0++)	• K*(892)	$1/2(1^{-})$	<ul> <li>D<sup>*</sup><sub>52</sub>(2573)</li> </ul>	0(2+)		0+(0/2+
<ul> <li>η'(958)</li> </ul>	0+(0-+)	$\eta$ (1760)	0+(0 - +)	• K <sub>1</sub> (1270)	$1/2(1^+)$	<ul> <li>D<sup>*</sup><sub>\$1</sub>(2700)<sup>±</sup></li> </ul>	0(1-)	• χ <sub>C2</sub> (3930)	$0^{+}(2^{+}+$ ??(???)
• f <sub>0</sub> (980)	$0^{+}(0^{++})$	<ul> <li>π(1800)</li> </ul>	$1^{-}(0^{-+})$	• K <sub>1</sub> (1400)	$1/2(1^+)$	$D_{51}^{+}(2860)^{\pm}$	0(1-)	X(3940)	?:(?::)
• a <sub>0</sub> (980)	$1^{-}(0^{++})$	$f_2(1810)$	$0^+(2^{++})$	• K*(1410)	$1/2(1^{-})$	$D_{53}^{+}(2860)^{\pm}$	0(3-)	• X(4020) <sup>±</sup>	1+(??-)
<ul> <li>φ(1020)</li> </ul>	$0^{-}(1^{-})$	X(1835)	?'(0 - +)	<ul> <li>K<sup>*</sup><sub>0</sub>(1430)</li> </ul>	$1/2(0^+)$	D <sub>sJ</sub> (3040) <sup>±</sup>		<ul> <li>ψ(4040)</li> </ul>	0-(1
<ul> <li>h<sub>1</sub>(1170)</li> </ul>	0-(1+-)	<ul> <li>φ<sub>3</sub>(1850)</li> </ul>	0-(3)	<ul> <li>K<sup>*</sup><sub>2</sub>(1430)</li> </ul>	$1/2(2^+)$			X(4050)±	$1^{-}(?^{?+})$
<ul> <li>b<sub>1</sub>(1235)</li> </ul>	$1^{+}(1^{+})$	<ul> <li>η<sub>2</sub>(1870)</li> </ul>	0+(2-+)	K(1460)	$1/2(0^{-})$	BOTT		X(4055)±	$1^{+}(?^{-})$
• a <sub>1</sub> (1260)	$1^{-}(1^{++})$	<ul> <li>π<sub>2</sub>(1880)</li> </ul>	1-(2-+)	$K_2(1580)$	$1/2(2^{-})$	(B =	±1)	$X(4100)^{\pm}$	1-(???)
<ul> <li>f<sub>2</sub>(1270)</li> </ul>	0+(2++)	ρ <b>(1900)</b>	1+(1)	K(1630)	$1/2(?^{?})$	• $B^{\pm}$	$1/2(0^{-})$	• $\chi_{c1}(4140)$	0+(1++
<ul> <li>f<sub>1</sub>(1285)</li> </ul>	$0^+(1^{++})$	$f_2(1910)$	0+(2++)	$K_1(1650)$	$1/2(1^+)$	• B <sup>0</sup>	$1/2(0^{-})$	<ul> <li>ψ(4160)</li> </ul>	$0^{-}(1^{-})^{-}$
<ul> <li>η(1295)</li> </ul>	0+(0-+)	$a_0(1950)$	$1^{-}(0^{++})$	• K*(1680)	$1/2(1^{-1})$	<ul> <li><i>B</i><sup>±</sup>/<i>B</i><sup>0</sup> AD</li> </ul>		X(4160)	? <sup>?</sup> (? <sup>??</sup> )
<ul> <li>π(1300)</li> </ul>	$1^{-}(0^{-+})$	• $f_2(1950)$	0+(2++)	• K <sub>2</sub> (1770)	$1/2(2^{-})$	• $B^{\pm}/B^{0}/B^{0}_{s}$	/b-baryon	$Z_{c}(4200)$	1+(1+-
• a <sub>2</sub> (1320)	$1^{-}(2^{++})$	<ul> <li>a<sub>4</sub>(1970)</li> </ul>	$1^{-}(4^{++})$	• K <sub>3</sub> (1780)	1/2(3-)	ADMIXTUI		<ul> <li>ψ(4230)</li> </ul>	0_(1
<ul> <li>f<sub>0</sub>(1370)</li> </ul>	$0^{+}(0^{++})$	ρ <sub>3</sub> (1990)	1+(3)	• K <sub>2</sub> (1820)	$1/2(2^{-})$	V <sub>cb</sub> and V <sub>ul</sub> trix ⊟emer	, CKM Ma-	$R_{c0}(4240)$	1+(0
<ul> <li>π<sub>1</sub>(1400)</li> </ul>	$1^{-}(1^{-+})$	$\pi_2(2005)$	$1^{-}(2^{-+})$	K(1830)	$1/2(0^{-1})$	• B*	1/2(1-)	$X(4250)^{\pm}$	$1^{-}(?^{+})$
<ul> <li>η(1405)</li> </ul>	0+(0-+)	<ul> <li>f<sub>2</sub>(2010)</li> </ul>	0+(2++)	$K_{0}^{*}(1950)$	$1/2(0^{+})$	• B1(5721)+	$1/2(1^+)$	$\psi$ (4260)	0-(1
<ul> <li>h<sub>1</sub>(1415)</li> </ul>	$0^{-}(1^{+-})$	f <sub>0</sub> (2020)	0+(0++)	K <sup>*</sup> <sub>2</sub> (1980)	$1/2(2^+)$	<ul> <li>B<sub>1</sub>(5721)<sup>0</sup></li> </ul>	$1/2(1^+)$	<ul> <li>χ<sub>c1</sub>(4274)</li> </ul>	0+(1++
$a_1(1420)$	$1^{-}(1^{++})$	<ul> <li>f<sub>4</sub>(2050)</li> </ul>	$0^{+}(4^{++})$	<ul> <li>K<sup>*</sup><sub>4</sub>(2045)</li> </ul>	$1/2(4^+)$	B <sup>*</sup> <sub>1</sub> (5732)	?(??)	X(4350)	0+(??+)
<ul> <li>f<sub>1</sub>(1420)</li> </ul>	0+(1++)	$\pi_2(2100)$	$1^{-}(2^{-+})$	$K_2(2250)$	$1/2(2^{-})$	<ul> <li>B<sup>*</sup><sub>2</sub>(5747)<sup>+</sup></li> </ul>	$1/2(2^+)$	<ul> <li>ψ(4360)</li> </ul>	0-(1
<ul> <li>ω(1420)</li> </ul>	0-(1)	fo(2100)	$0^{+}(0^{++})$	K <sub>3</sub> (2320)	$1/2(3^+)$	<ul> <li>B<sup>*</sup><sub>2</sub>(5747)<sup>0</sup></li> </ul>	$1/2(2^+)$	$\psi$ (4390)	0-(1
f <sub>2</sub> (1430)	$0^{+}(2^{++})$	f <sub>2</sub> (2150)	$0^{+}(2^{++})$	K <sup>*</sup> <sub>5</sub> (2380)	1/2(5)	B <sub>1</sub> (5840) <sup>+</sup>	$1/2(?^{?})$	<ul> <li>ψ(4415)</li> </ul>	0-(1
• a <sub>0</sub> (1450)	$1^{-}(0^{++})$	ρ <b>(2150)</b>	1+(1)	$K_4(2500)$	$1/2(4^{-})$	B <sub>1</sub> (5840) <sup>0</sup>	$1/2(?^{?})$	<ul> <li>Z<sub>c</sub>(4430)</li> </ul>	1+(1+-
<ul> <li>ρ(1450)</li> </ul>	1+(1)	<ul> <li>φ(2170)</li> </ul>	0-(1)	K(3100)	??(???)	• B <sub>1</sub> (5970) <sup>+</sup>	$1/2(?^{?})$	χ <sub>c0</sub> (4500)	0+(0++
<ul> <li>η(1475)</li> </ul>	0+(0-+)	f <sub>0</sub> (2200)	0+(0++)	N(3100)	· (· )	• B <sub>1</sub> (5970) <sup>0</sup>	$1/2(?^{?})$	<ul> <li>ψ(4660)</li> </ul>	0-(1
<ul> <li>f<sub>0</sub>(1500)</li> </ul>	0+(0++)	f_(2220)	0+(2++	CHARM				$\chi_{c0}(4700)$	0+(0++
$f_1(1510)$	0+(1++)		or 4 <sup>++</sup> )	(C = ±	=1)	BOTTOM,		b	τ
<ul> <li>f'<sub>2</sub>(1525)</li> </ul>	0+(2++)	η(2225)	0+(0-+)	<ul> <li>D<sup>±</sup></li> </ul>	$1/2(0^{-})$	$(B = \pm 1,$	$S = \mp 1$ )	D (+ possibly n	
$f_2(1565)$	$0^+(2^{++})$	ρ <sub>3</sub> (2250)	1+(3)	• D <sup>0</sup>	$1/2(0^{-})$	• B <sup>0</sup> <sub>s</sub>	0(0-)		
ρ <b>(1570)</b>	1+(1)	<ul> <li>f<sub>2</sub>(2300)</li> </ul>	0+(2++)	<ul> <li>D*(2007)<sup>0</sup></li> </ul>	$1/2(1^{-})$	• B <sup>*</sup> <sub>s</sub>	$0(1^{-})$	<ul> <li>η<sub>b</sub>(1S)</li> </ul>	0+(0 - +
$h_1(1595)$	0-(1+-)	f <sub>4</sub> (2300)	$0^{+}(4^{++})$	<ul> <li>D*(2010)<sup>±</sup></li> </ul>	$1/2(1^{-})$	$X(5568)^{\pm}$	?(??)	<ul> <li> <i>γ</i>(1S)     </li> </ul>	0-(1
<ul> <li>π<sub>1</sub>(1600)</li> </ul>	$1^{-}(1^{-+})$	f <sub>0</sub> (2330)	0+(0++)	<ul> <li>D<sup>*</sup><sub>0</sub>(2300)<sup>0</sup></li> </ul>	$1/2(0^+)$	• B <sub>s1</sub> (5830) <sup>0</sup>	0(1+)	<ul> <li>         χ<sub>b0</sub>(1P)         </li> </ul>	$0^{+}(0^{++})$
• a <sub>1</sub> (1640)	$1^{-}(1^{++})$	<ul> <li>f<sub>2</sub>(2340)</li> </ul>	0+(2++)	$D_0^*(2300)^{\pm}$	$1/2(0^{+})$	<ul> <li>B<sup>*</sup><sub>52</sub>(5840)<sup>0</sup></li> </ul>	$0(2^{+})$	• $\chi_{b1}(1P)$	$0^{+}(1^{++})$
f2(1640)	$0\pm (0\pm \pm)$	ρ <sub>5</sub> (2350)	1+(5)	<ul> <li>D<sub>1</sub>(2420)<sup>0</sup></li> </ul>	1/2(1+)	B* (5850)	?(??)	• $h_b(1P)$	$0^{-}(1^{+-})$
<ul> <li>η<sub>2</sub>(164<sup>F</sup>)</li> </ul>		$f_6(2510)$	0+(6++)	D1(2420)±	$1/2(?^{?})$		( )	• $\chi_{b2}(1P)$	$0^{+}(2^{++})$
• \u03c6 (16	-	OTHER	RLIGHT	$D_1(2430)^0$	$1/2(1^{+})$	BOTTOM,		$\eta_{b}(25)$	$0^{+}(0^{-+})$
• w3				<ul> <li>D<sup>*</sup><sub>2</sub>(2460)<sup>0</sup></li> </ul>	1/2(2+)	(B = C		<ul> <li> <i>\(\color\)</i>         (25) \(\color\)         (15)         </li> </ul>	0-(1
		her St	aucs	<ul> <li>D<sub>2</sub><sup>+</sup>(2460)<sup>±</sup></li> </ul>	$1/2(2^+)$	• B_{c}^{+}	0(0^)	<ul> <li> <i>\gamma_2(1D)</i> </li> </ul>	0-(2
				$D(2550)^0$	$1/2(?^{?})$	$B_c(2S)^{\pm}$	0(0-)	<ul> <li>         χ<sub>b0</sub>(2P)         </li> </ul>	$0^{+}(0^{++})$
				$D^{*}(2600)$	1/2(??)			<ul> <li>         χ<sub>b1</sub>(2P)         </li> </ul>	$0^{+(1^{++})}$
				D*(2640) <sup>±</sup>	$1/2(?^{?})$	כת (+ possibly no		$h_b(2P)$	$0^{-}(1^{+-})$
				D(2740) <sup>0</sup>	$1/2(?^{?})$			<ul> <li>         χ<sub>b2</sub>(2P)         </li> </ul>	0+(2++
				$D_{3}^{(2740)}$	1/2(3)	• $\eta_c(1S)$	0+(0 - +)	<ul> <li> <i>Υ</i>(35)         <ul> <li></li></ul></li></ul>	0-(1
				$D_{3}(2130)^{0}$ $D(3000)^{0}$	$1/2(3^{\circ})$ $1/2(?^{\circ})$	<ul> <li>J/ψ(1S)</li> </ul>	$0^{-}(1^{-})$	<ul> <li>         χ<sub>b1</sub>(3P)     </li> </ul>	$0^{+}(1^{++})$
		1		2(300)	±/2(: )	• v <sub>10</sub> (1P)	0+(0++)	<ul> <li>         χ<sub>b2</sub>(3P)     </li> </ul>	0+(2++
						$_{:1}(1P)$	0+(1++)	<ul> <li> <i>Υ</i>(4S)     </li> </ul>	0-(1
	~ 1	<b>^</b> -				:(1P)	0-(1+-)	• $Z_b(10610)$	
	-71	() Y	me	SO	nc	_2(1P)	0+(2++)	<ul> <li>Z<sub>b</sub>(10650)</li> </ul>	$1^+(1^+)^-$
		U I		30		:(25)	0+(0 - +)	$\Upsilon(10753)$	??(1 )
						(2 <i>S</i> )	0-(1)	<ul> <li> <i>Υ</i>(10860)         <ul> <li> <i>Υ</i>(11020)             </li> </ul> </li> </ul>	$0^{-}(1^{-})^{-}$ $0^{-}(1^{-})^{-}$

## **Observed hadrons (2022)**

### Particle Data Group (PDG) 2022 eddition

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	(COLORIDA)				<u> </u>					1								CTDA	NCE			_
	р	1/2+ ****	∆(1232)	3/2+ ****	$\Sigma^+$	1/2+ *	L	$1/2^{+}$	****	$\Lambda_{D}^{0}$	$1/2^{+}$				(S = C)	FLAVORED = $B = 0$ )		STRA (S = ±1, C	= B = 0)	CHARMED, STRANGE ( $C = \pm 1$ , $S = \pm 1$ )	$c\overline{c} \text{ continued}$ $P(P^{C})$	)
	n	1/2+ ****	$\Delta(1600)$	3/2+ ****		1/2+ *	1.0(205)	5)+ 1/2-	***		$1/2^{-}$				$P(f^{C})$		$I^{G}(J^{PC})$		<i>l(𝔅</i> )	$(+ \text{ possibly non-}q\overline{q} \text{ state} I(J^{P})$	• ψ <sub>2</sub> (3823) 0 <sup>-</sup> (2 <sup>-</sup>	)
/ <mark>7</mark>	N(1440)	1/2+ ****	<i>∆</i> (1620)	1/2 ****	<u> </u>	1/2+ *			***	$\Lambda_{b}(5920)^{0}$	3/2	***		• $\pi^{\pm}$	$1^{-}(0^{-})$	<ul> <li>π<sub>2</sub>(1670)</li> </ul>	$1^{-}(2^{-+})$	• K <sup>±</sup>	1/2(0-)		<ul> <li>ψ<sub>3</sub>(3842) 0<sup>-</sup>(3<sup>-</sup></li> <li>φ<sub>3</sub>(3842) 0<sup>+</sup>(3<sup>+</sup></li> </ul>	· -)
1	N(1520)	3/2 ****	$\Delta(1700)$	3/2 <sup>—</sup> ****	-(1000)	3/2+ *			*		5/2			• π <sup>0</sup> • η	$1^{-}(0^{-}+)$ $0^{+}(0^{-}+)$	<ul> <li>φ(1680)</li> <li>ρ<sub>3</sub>(1690)</li> </ul>	$0^{-}(1^{-})$ $1^{+}(3^{-})$	• K <sup>0</sup>	1/2(0 <sup></sup> ) 1/2(0 <sup></sup> )	• $D_s^{\pm}$ 0(0 <sup>-</sup> ) • $D_s^{\pm\pm}$ 0(? <sup>?</sup> )	$\chi_{c0}(3860)  0^+(0^+)$ • $\chi_{c1}(3872)  0^+(1^+)$	
	N(1535)	1/2 ****	$\Delta(1750)$	1/2+ *	$\Sigma(1580)$	3/2 *		$3)^{+} 3/2^{+}$		$\Lambda_{b}(6152)^{0}$	5/2	***		<ul> <li>f<sub>0</sub>(500)</li> </ul>	$0^{+}(0^{+}^{+})$		$1^{+}(1^{-})$	• K9	$1/2(0^{-})$	<ul> <li>D<sup>s</sup><sub>s0</sub>(2317)<sup>±</sup> 0(0<sup>+</sup>)</li> </ul>	• $Z_c(3900)$ 1+(1+	
	N(1650)	$1/2^{-}$ **** $5/2^{-}$ ****	$\Delta(1900)$	1/2 <sup>-</sup> *** 5/2 <sup>+</sup> ****	$\Sigma(1620)$	$\frac{1}{2^{-}} *$ $\frac{1}{2^{+}} *$		$()^+ 5/2^+$		$\Sigma_b$	$1/2^+$			<ul> <li>ρ(770)</li> </ul>	1+(1)	<ul> <li>a<sub>2</sub>(1700)</li> </ul>	$1^{-}(2^{++})$	• K <sub>0</sub> (700)	1/2(0+)	• $D_{S1}(2460)^{\pm} = 0(1^{+})$	<ul> <li> <i>χ</i><sub>c0</sub>(3915) 0<sup>+</sup>(0<sup>+</sup> </li> </ul>	
	N(1675) N(1680)	5/2 **** 5/2 <sup>+</sup> ****	$\Delta(1905)$ $\Delta(1910)$	5/2 +++++ 1/2 + ****	$\Sigma(1660)$ $\Sigma(1670)$	3/2 *				$\Sigma_b^*$	3/2+	***		• ω(782) • η′(958)	$0^{-}(1^{-})$ $0^{+}(0^{-})$	<ul> <li>f<sub>0</sub>(1710)</li> <li>X(1750)</li> </ul>	$0^+(0^+)$	<ul> <li>K*(892)</li> </ul>	$\frac{1}{2(1^{-})}$ $\frac{1}{2(1^{+})}$	• $D_{S1}(2536)^{\pm}$ 0(1 <sup>+</sup> ) • $D_{S2}^{*}(2573)$ 0(2 <sup>+</sup> )	• $\chi_{C2}(3930) = 0^+(2^+)^+$ X(3940) ??(???)	<sup>+</sup> )
	N(1000)	3/2 ***	$\Delta(1910)$ $\Delta(1920)$	3/2+ ***	$\Sigma(1070)$	1/2 *			***	$\Sigma_b(6097)^+$ $\Sigma_b(6097)^-$		***		• f <sub>0</sub> (980)	$0^{+}(0^{+}^{+})$	$\eta(1760)$	$0^+(0^-+)$	<ul> <li>K<sub>1</sub>(1270)</li> <li>K<sub>1</sub>(1400)</li> </ul>	$\frac{1/2(1^+)}{1/2(1^+)}$	$D_{s2}(2573)^+$ $0(2^+)^-$	• $X(4020)^{\pm}$ 1 <sup>+</sup> (? <sup>-</sup>	-)
	N(1700)	1/2+ ****	$\Delta(1920)$ $\Delta(1930)$	5/2 ***	$\Sigma(1750)$	5/2 *	*** $\Sigma_{c}(232)$		***	Zb(0097)	$1/2^{+}$			<ul> <li>a<sub>0</sub>(980)</li> </ul>	$1^{-}(0^{++})$	<ul> <li>π(1800)</li> </ul>	1-(0-+)	• K*(1410)	$1/2(1^{-})$	<ul> <li>D<sup>*</sup><sub>51</sub>(2700)<sup>±</sup> 0(1<sup>−</sup>)</li> </ul>	<ul> <li>ψ(4040) 0<sup>-</sup>(1<sup>-</sup></li> </ul>	( <sup>-</sup> )
	N(1720)	3/2+ ****	$\Delta(1940)$	3/2- **	$\Sigma(1780)$	3/2+ *	$\Xi_{c}^{+}$	1/2+	***	-b =0 = b	$1/2^+$			<ul> <li>φ(1020)</li> <li>h<sub>1</sub>(1170)</li> </ul>	$0^{-}(1^{-})$ $0^{-}(1^{+})$	f <sub>2</sub> (1810) X(1835)	$^{0^+(2^{++})}_{?^{?}(0^{-+})}$	• K <sub>0</sub> (1430)	1/2(0+)	$D_{S1}^{*}(2860)^{\pm} 0(1^{-})$	$X(4050)^{\pm}$ 1 <sup>-</sup> (? <sup>?+</sup> $X(4055)^{\pm}$ 1 <sup>+</sup> (? <sup>?-</sup>	-)
	N(1860)	5/2+ **	$\Delta(1950)$	7/2+ ****	$\Sigma(1880)$	1/2+ *		1/2+	****	$\frac{-b}{\Xi'_{b}(5935)^{-}}$		***		• b1(1235)	$1^{+}(1^{+})$	• $\phi_3(1850)$	0-(3)	<ul> <li>K<sub>2</sub>(1430)</li> <li>K(1460)</li> </ul>	1/2(2 <sup>+</sup> ) 1/2(0 <sup>-</sup> )	• $D_{s3}^*(2860)^{\pm} 0(3^{-})$ $X_0(2900) ?(0^{+})$	$X(4000)^{\pm} 1^{-}(?^{?})^{\pm}$	5
	N(1875)	3/2- ***	$\Delta(2000)$	5/2 <sup>+</sup> **	Σ(1900)	1/2- *	* ='+	1/2+		$\Xi_b(5945)^0$		***		• a1(1260)	$1^{-}(1^{++})$	<ul> <li>η<sub>2</sub>(1870)</li> </ul>	0+(2 - +)	$K_2(1580)$	$1/2(0^{-})$	$X_1(2900)$ ?(1 <sup>-</sup> )	• $\chi_{c1}$ (4140) 0 <sup>+</sup> (1 <sup>+</sup>	- <sup>(+</sup> )
	N(1880)	1/2+ ***	<i>∆</i> (2150)	1/2- *	Σ(1910)	3/2- *	* $=_{c}^{+}$ ** $=_{c}^{0}$	1/2+				***		• f <sub>2</sub> (1270)	$0^+(2^{++})$		$1^{-}(2^{-+})$	K(1630)	1/2(??)	$D_{sJ}(3040)^{\pm} 0(?^{?})$	• $\psi(4160) = 0^{-}(1^{-})^{-}$ X(4160) ??(???)	(-)
	N(1895)	1/2 ****	<i>∆</i> (2200)	7/2 ***	Σ(1915)	5/2+ *	Ξ-(264		***		3/2-	***		<ul> <li>f<sub>1</sub>(1285)</li> <li>η(1295)</li> </ul>	$0^+(1^{++})$ $0^+(0^{-+})$	ρ(1900) f <sub>2</sub> (1910)	$1^+(1^{})$ $0^+(2^{++})$	<ul> <li>K<sub>1</sub>(1650)</li> <li>K<sup>*</sup>(1680)</li> </ul>	$\frac{1}{2(1^+)}$ $\frac{1}{2(1^-)}$	BOTTOM	$Z_c(4200)$ 1 <sup>+</sup> (1 <sup>+</sup> )	
1	N(1900)	3/2+ ****	<i>∆</i> (2300)	9/2+ **	Σ(1940)	3/2+ *	=(279)			$\Xi_b(6227)^-$		***		<ul> <li>π(1300)</li> </ul>	1-(0-+)	$a_0(1950)$	$1^{-}(0^{++})$	• K <sup>*</sup> (1680) • K <sub>2</sub> (1770)	$\frac{1}{2(1)}$ $\frac{1}{2(2^{-})}$	(B = ±1)	<ul> <li>ψ(4230)</li> <li>0<sup>-</sup>(1<sup>-</sup></li> </ul>	· - j
	N(1990)	7/2+ **	<i>∆</i> (2350)	5/2 *	Σ(2010)	3/2 *	= (281)			$\Xi_{b}(6227)^{0}$		***		• a2(1320)	$1^{-}(2^{++})$	<ul> <li>f<sub>2</sub>(1950)</li> </ul>	$0^+(2^++)$	<ul> <li>K<sup>*</sup><sub>3</sub>(1780)</li> </ul>	1/2(3-)	<ul> <li>B<sup>±</sup></li> <li>1/2(0<sup>−</sup></li> <li>B<sup>0</sup></li> <li>1/2(0<sup>−</sup></li> </ul>	) $R_{c0}(4240)$ 1 <sup>+</sup> (0 <sup>-</sup> )	)
	N(2000)	5/2 <sup>+</sup> **	<i>∆</i> (2390)	7/2+ *	$\Sigma(2030)$	7/2+ *	*** E <sub>c</sub> (292	3)	**	$\Omega_b^-$	$1/2^{+}$	***		<ul> <li>f<sub>0</sub>(1370)</li> <li>π<sub>1</sub>(1400)</li> </ul>	$0^+(0^{++})$ $1^-(1^{-+})$	<ul> <li> <i>∂</i><sub>4</sub>(1970) <i>ρ</i><sub>3</sub>(1990)         </li> </ul>	$1^{-}(4^{++})$ $1^{+}(3^{})$	<ul> <li>K<sub>2</sub>(1820)</li> <li>K(1920)</li> </ul>	1/2(2 <sup>-</sup> ) 1/2(0 <sup>-</sup> )	• B <sup>0</sup> 1/2(0 <sup>−</sup> • B <sup>±</sup> /B <sup>0</sup> ADMIXTURE	$\begin{array}{c} X(4250)^{\pm} & 1^{-}(?^{!+}) \\ \bullet \chi_{c1}(4274) & 0^{+}(1^{+}) \end{array}$	
	N(2040)	3/2 <sup>+</sup> *	$\Delta(2400)$	9/2 <sup>-</sup> **	Σ(2070)	5/2+ *	-2(2)5		**	Ω <sub>b</sub> (6316)-		*		<ul> <li>η(1405)</li> </ul>	0+(0 - +)	$\pi_2(2005)$	$1^{-}(2^{-}+)$	K(1830) K <sub>0</sub> (1950)	$1/2(0^{-1})$ $1/2(0^{+})$	<ul> <li>B<sup>±</sup>/B<sup>0</sup>/B<sup>0</sup><sub>s</sub>/b-baryon</li> </ul>	X(4350) 0 <sup>+</sup> (? <sup>?+</sup>	
	N(2060) N(2100)	5/2 <sup>-</sup> *** 1/2 <sup>+</sup> ***	$\Delta(2420)$	11/2 <sup>+</sup> **** 13/2 <sup>-</sup> **	$\Sigma(2080)$	3/2 <sup>+</sup> * 7/2 <sup>-</sup> *	-C(251			Ω <sub>b</sub> (6330) <sup>-</sup>		*		<ul> <li>h1(1415)</li> </ul>	$0^{-}(1^{+-})$	• f <sub>2</sub> (2010)	$0^{+}(2^{++})$	• K <sub>2</sub> (1980)	$1/2(0^{+})$	ADMIXTURE V <sub>cb</sub> and V <sub>ub</sub> CKM Ma	<ul> <li>ψ(4360) 0<sup>-</sup>(1<sup>-</sup></li> <li>ψ(4415) 0<sup>-</sup>(1<sup>-</sup></li> </ul>	
	N(2100)	3/2 ***	$\Delta(2750)$ $\Delta(2950)$	15/2 ++ 15/2 <sup>+</sup> **	$\Sigma(2100)$ $\Sigma(2110)$	1/2 *			***	$\Omega_{b}(6340)^{-}$		*		<ul> <li>f<sub>1</sub>(1420)</li> <li>ω(1420)</li> </ul>	$0^+(1^++)$ $0^-(1^)$	$f_0(2020)$ • $f_4(2050)$	$0^+(0^{++})$ $0^+(4^{++})$	• K <sub>4</sub> <sup>*</sup> (2045)	1/2(4+)	trix Elements	• $\psi(4415) = 0 = (1 + 1)^{-1}$	
	N(2120)	7/2 ****	<u>Д(2950)</u>	15/2	$\Sigma(2110)$	3/2+ *		0)	***	$\Omega_{b}(6350)^{-}$		*		f <sub>2</sub> (1430)	0+(2++)	$\pi_2(2100)$	1-(2-+)	$K_2(2250)$ $K_3(2320)$	1/2(2 <sup>-</sup> ) 1/2(3 <sup>+</sup> )	• B <sup>*</sup> 1/2(1 <sup>−</sup> • B <sub>1</sub> (5721) 1/2(1 <sup>−</sup>	7 <u>55 6 6 6</u>	
	N(2220)	9/2+ ****	Λ	1/2+ ****	$\Sigma(2250)$	\$		3) 1/2 <sup>+</sup>	***	$P_{c}(4312)^{+}$		*		<ul> <li>a<sub>0</sub>(1450)</li> <li>a(1450)</li> </ul>	$1^{-}(0^{++})$	f <sub>0</sub> (2100)	$0^+(0^{++})$ $0^+(2^{++})$	K <sup>*</sup> <sub>5</sub> (2380)	1/2(5)	B <sup>*</sup> <sub>J</sub> (5732) ?(? <sup>?</sup> )	X(4630) 0 <sup>+</sup> (? <sup>!+</sup>	F)
	N(2250)	9/2- ****	<i>A</i> (1380)	1/2 **	_ ()		175	1/2 .		F7(4312)				• 0(1450)	1+(1)	£(2150)	0.17.1.1			$- B_2^*(5747) = 1/2(2^+)$ $3_1(5840) = 1/2(?^2)$		+
	N(2300)	1/2+ **	/(1405)	1/2 **																	χ <sub>c0</sub> (4700) 0 <sup>+</sup> (0 <sup>+</sup>	<sup>+</sup> )
	N(2570)	5/2- **	A(1520)	3/2 <sup>-</sup> *9 1/2 <sup>+</sup> *9	nev	<b>///</b>		nc	ρι	rve		n	adro	n	C 11	n 7	' VI	Pal	r <b>C</b> I	OTTOM, STRANGE	b <del>b</del>	
	N(2600)	11/2- ***	A(1600)	1/2+***							M		umic				- y'	Gui		$(B = \pm 1, S = \mp 1)$	$(+ possibly non q \overline{q} states)$	ates)
· · · · · · · · · · · · · · · · · · ·	N(2700)	13/2+ **	A(1670)	1/2 <sup>-</sup> ** 3/2 <sup>-</sup> ****	-0	1/0+ *	*** 1	~,		i		i			5.1.3				4-1-1-1	3 <sup>0</sup> <sub>5</sub> 0(0 <sup>-</sup> )	• η <sub>b</sub> (1S) 0 <sup>+</sup> (0 <sup>-</sup>	(+)
			$\Lambda(1690)$	3/2 1/2+ *	12.	$\frac{1}{2^{+}} *$ $\frac{1}{2^{+}} *$	*** Ω <sub>c</sub> (312	0) <sup>0</sup>	***					$h_1(1595)$ • $\pi_1(1600)$	$0^{-}(1^{+})$ $1^{-}(1^{-})$	$\rho_3(2250)$ • $f_2(2300)$	$1^{+}(3^{-})$ $0^{+}(2^{+})$	<ul> <li>D<sup>*</sup>(2007)<sup>0</sup></li> <li>D<sup>*</sup>(2010)<sup>±</sup></li> </ul>	$\frac{1}{2(1^{-})}$ $\frac{1}{2(1^{-})}$	• $B_s^* = 0(1^-)$ $\chi(5568)^{\pm} ?(?^?)$	• $\gamma(15)$ 0 <sup>-</sup> (1 <sup>-</sup> • $\chi_{b0}(1P)$ 0 <sup>+</sup> (0 <sup>+</sup>	-+)
			1(1800)	1/2- ***		3/2+ *	***		*					• a1(1640)	$1^{-}(1^{++})$		$0^{+}(4^{++})$	• D' (2010)= • D <sub>0</sub> (2300)	$\frac{1}{2(1)}$ $\frac{1}{2(0^+)}$	• $B_{s1}(5830)^0$ $0(1^+)$	• $\chi_{b1}(1P) = 0^+(1^+)^+$	·+j
			A(1810)	1/2+ ***	$\Xi(1620)$	*	$=_{cc}$		***					$f_2(1640)$	$0^+(2^{++})$		$0^{+}(0^{++})$	<ul> <li>D<sub>1</sub>(2420)</li> </ul>	$1/2(1^+)$	• $B_{\underline{s}2}^{*}(5840)^{0} = 0(2^{+})$	• $h_b(1P) = 0^-(1^+)^+$ • $\chi_{b2}(1P) = 0^+(2^+)^+$	
<b>//</b> 3	*, Δ	*	A(1820)	5/2+ ****	Ξ(1690)	*	** =		***					<ul> <li>η<sub>2</sub>(1645)</li> <li>ω(1650)</li> </ul>	$0^+(2^{-+})$	<ul> <li><i>t</i><sub>2</sub>(2340)</li> <li><i>ρ</i><sub>5</sub>(2350)</li> </ul>	$0^+(2^{++})$ $1^+(5^{})$	<ul> <li>D<sub>1</sub>(2430)<sup>0</sup></li> <li>D<sup>*</sup>(2430)</li> </ul>	$1/2(1^+)$	$B_{s,J}^*(5850)$ ?(??)	• $\chi_{b2}(1P)$ 0 <sup>+</sup> (2 <sup>+</sup> ) $\eta_b(2S)$ 0 <sup>+</sup> (0 <sup>-</sup> )	
1 1	· , 🗕		A(1830)	5/2 ****	Ξ(1820)	3/2 *	**							<ul> <li>ω<sub>3</sub>(167°</li> </ul>		X(2370)	??(???)	<ul> <li>D<sup>*</sup><sub>2</sub>(2460)</li> <li>D<sup>*</sup><sub>0</sub>(2550)<sup>0</sup></li> </ul>	1/2(2 <sup>+</sup> ) 1/2(0 <sup>-</sup> )	$B_{sJ}(6063)^0 = 0(?^{t})$ $B_{sJ}(6114)^0 = 0(?^{t})$	<ul> <li> <i>γ</i>(2S) 0<sup>−</sup>(1<sup>−</sup> </li> </ul>	· j
			A(1890)	3/2+ ****	Ξ(1950)		**									2510)	0+(6++)	D*(2600) <sup>0</sup>	$1/2(0^{-})$ $1/2(1^{-})$	BOTTOM, CHARMEE	• $\gamma_2(1D)$ 0 <sup>-</sup> (2 <sup>-</sup> ) • $\chi_{b0}(2P)$ 0 <sup>+</sup> (0 <sup>+</sup> )	
			<i>N</i> (2000)	1/2- *	Ξ(2030)	$\geq \frac{5}{2}$ *	**											D*(2640)±	1/2(??)	$(B = C = \pm 1)$	• $\chi_{b0}(2P)$ 0 (0 • $\chi_{b1}(2P)$ 0 <sup>+</sup> (1 <sup>+</sup>	
	1		A(2050)	3/2 *	Ξ(2120)	*												$D_2(2740)^0$ • $D_3^*(2750)$	1/2(2 <sup></sup> ) 1/2(3 <sup></sup> )	• B <sub>c</sub> <sup>+</sup> 0(0 <sup>-</sup> )	• h <sub>b</sub> (2P) 0 <sup>-</sup> (1 <sup>+</sup>	j
	1		A(2070)	3/2 <sup>+</sup> *	$\Xi(2250)$	*	*											$D_1^*(2760)^0$	1/2(1_)	• $B_c(2S)^{\pm}$ 0(0 <sup>-</sup> )	• $\chi_{b2}(2P)$ 0 <sup>+</sup> (2 <sup>+</sup> • $\Upsilon(3S)$ 0 <sup>-</sup> (1 <sup>-</sup>	
	1		A(2080) A(2085)	5/2 <sup>-</sup> * 7/2 <sup>+</sup> **	$\Xi(2370)$	*	Φ.											D(3000) <sup>0</sup>	1/2(??)	CC	• YE1 (3P) 0+(1+	-+)
	1		$\Lambda(2000)$	7/2 ****	<i>Ξ</i> (2500)	*						,								$(+ \text{ possibly non} - q \overline{q} \text{ state}$	• Xb2(SP) 0 (2	-+)
	1		A(2100)	5/2 <sup>+</sup> ***	$\Omega^{-}$	3/2+ *	***													• $\eta_c(1S) = 0^+(0^- + 0^-)^+$ • $J/\psi(1S) = 0^-(1^ 0^-)^+$	$\gamma(4S) = 0^{-1}(1^{-1})$ $\cdot Z_b(10610) = 1^{+1}(1^{+1})$	
			A(2325)	3/2 *	Ω(2012	-, -										-				(1P) 0 <sup>+</sup> (0 <sup>++</sup>	) • $Z_b(10650)$ 1 <sup>+</sup> (1 <sup>+</sup>	
	1		A(2350)	9/2+ ***		- <b>-</b>	70								<b>1</b>	Λ-				(1P) 0 <sup>+</sup> (1 <sup>++</sup> 1P) 0 <sup>-</sup> (1 <sup>+-</sup>	$ \begin{array}{c} \gamma(10753) & ?^{?}(1 - 1) \\ \bullet & \gamma(10860) & 0^{-}(1 - 1) \end{array} $	-)
	1		A(2585)	*	Ω(238) Ω(247)	~	70	Da	r\	vor	15			~	/Z 1	U	me	so	<u>en</u>	$(1P) 0^{+}(2^{++})$	$\gamma(1030) = 0 = (1 - 1)$	
	1				Ω(247(				•• J							<b>•</b>					) OTHER	
	1						1		_	I						i i	j	l i	j	S) 0 <sup>-</sup> (1 <sup></sup> •ψ(3770) 0 <sup>-</sup> (1 <sup></sup>	) Further States	
	h																			, (31.0) 0 (4	41	

### All ~ 380 hadrons emerge from single QCD Lagrangian

## **Unstable states via strong interaction**

### Stable/unstable hadrons

#### http://pdg.lbl.gov/

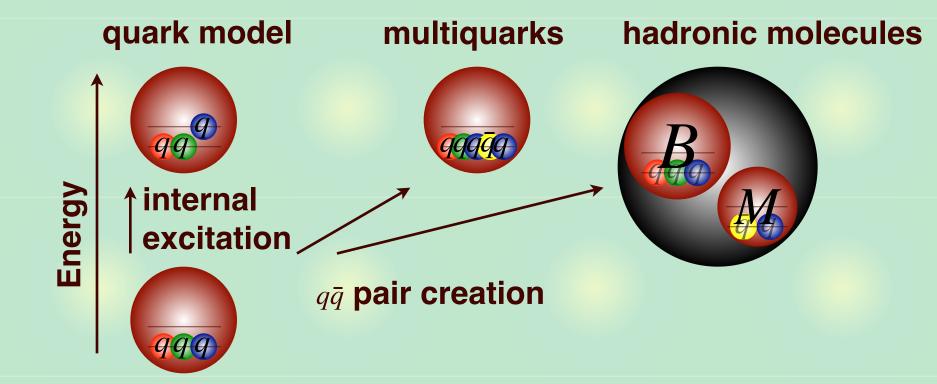
р		****	⊿(1232)	3/2+	****	$\Sigma^+$	$1/2^{+}$	****	$\Lambda_c^+$	$1/2^{+}$	****	$\Lambda_b^0$	$1/2^{+}$	***
п	1/2+ 3	****	$\Delta(1600)$	3/2+	****	$\Sigma^0$	$1/2^{+}$	****	$\Lambda_{c}(2595)^{+}$	$1/2^{-}$	***	$\Lambda_{b}(5912)^{0}$	$1/2^{-}$	***
N(1440)	1/2+ 3	****	⊿(1620)	$1/2^{-}$	****	$\Sigma^{-}$	-/-	****	$\Lambda_{c}(2625)^{+}$	3/2-	***	$\Lambda_b(5920)^0$	3/2-	***
N(1520)	3/2- 3	****	$\Delta(1700)$	3/2-	****	Σ(1385)	3/2+	****	$\Lambda_{c}(2765)^{+}$		*	$\Lambda_{b}(6146)^{0}$	3/2+	***
N(1535)	1/2- 3	****	⊿(1750)	$1/2^{+}$	*	Σ(1580)	3/2-	*	$\Lambda_{c}(2860)^{+}$	3/2+	***	$\Lambda_{b}(6152)^{0}$	5/2+	***
N(1650)	1/2- 3	****	⊿(1900)	1/2-	***	$\Sigma(1620)$	1/2-	*	$\Lambda_{c}(2880)^{+}$	$5/2^{+}$	***	$\Sigma_b$	1/2+	***
N(1675)	5/2- 3	****	⊿(1905)	5/2+	****	$\Sigma(1660)$	$1/2^{+}$	***	$\Lambda_{c}(2940)^{+}$	3/2-	***	$\Sigma_{b}^{*}$	3/2+	***
N(1680)	5/2+ 3	****	$\Delta(1910)$	$1/2^{+}$	****	Σ(1670)	3/2-	****	$\Sigma_{c}(2455)$	$1/2^{+}$	****	$\Sigma_{b}^{\nu}(6097)^{+}$		***
N(1700)	3/2- 3	***	$\Delta(1920)$	3/2+	***	Σ(1750)	$1/2^{-}$	***	$\Sigma_{c}(2520)$	3/2+	***	$\Sigma_{b}(6097)^{-}$		***
N(1710)	1/2+ 3	****	⊿(1930)	5/2-	***	Σ(1775)	5/2-	****	$\Sigma_{c}(2800)$	<i>'</i>	***	$\Xi_{b}^{-}$	$1/2^{+}$	***
N(1720)	3/2+ 3	****	⊿(1940)	3/2-	*ok	Σ(1780)	3/2+	*	$\Xi_c^+$	$1/2^{+}$	***	=0	1/2+	***
N(1860)	5/2+ 3	**	$\Delta(1950)$	7/2+	****	Σ(1880)	$1/2^{+}$	**	=0	$1/2^{+}$	****	$\Xi'_{b}(5935)^{-}$		***
N(1875)	3/2- 3	***	$\Delta(2000)$	5/2+	*ok	Σ(1900)	$1/2^{-}$	**	=0 c+ =c+	$1/2^{+}$	***	$\Xi_b(5945)^0$	3/2+	***
N(1880)	1/2+ 3	***	$\Delta(2150)$	$1/2^{-}$	*	Σ(1910)	3/2-	***	$=_{c}^{c}$	$1/2^+$	***	$\Xi_{b}(5955)^{-}$		***
N(1895)	1/2- 3	****	$\Delta(2200)$	7/2-	***	Σ(1915)	5/2+	****	=c =c(2645)	3/2+	***	$\Xi_b(6100)^-$		***
N(1900)	3/2+ 3	****	<i>∆</i> (2300)́	9/2+	**	Σ(1940)	3/2+	*	$\Xi_c(20+3)$ $\Xi_c(2790)$	$1/2^{-1}$	***	$\Xi_b(6227)^-$	3/2	***
N(1990)	7/2+ 3	**	$\Delta(2350)$	5/2-	*	Σ(2010)	3/2-	*	$\Xi_{c}(2815)$	3/2-	***	$\Xi_b(6227)^0$		***
N(2000)		**	$\Delta(2390)$	7/2+	*	Σ(2030)	7/2+	****	$\Xi_c(2013)$ $\Xi_c(2923)$	5/2	**	$\Omega_b^-$	1/2+	***
N(2040)		*	<i>∆</i> (2400)	9/2-		Σ(2070)	5/2+	*	$\Xi_c(2923)$ $\Xi_c(2930)$		**		1/2	*
N(2060)		***	$\Delta(2420)$	11/2+		Σ(2080)	3/2+	*	$\Xi_c(2930)$ $\Xi_c(2970)$	$1/2^{+}$	***	$\Omega_b(6316)^-$ $\Omega_b(6330)^-$		*
N(2100)	1/2+ 3	***	$\Delta(2750)$	13/2-		$\Sigma(2100)$	7/2-	*	$\Xi_c(3055)$	1/2	***			*
N(2120)		***	$\Delta(2950)$	15/2+		Σ(2110)	1/2-	*	$\Xi_c(3055)$ $\Xi_c(3080)$		***	$\Omega_b(6340)^-$		*
N(2190)		****	· · /			Σ(2230)	3/2+	*	$\Xi_c(3080)$ $\Xi_c(3123)$		*	$\Omega_{b}(6350)^{-1}$		
N(2220)		****	Λ	$1/2^{+}$	****	Σ(2250)	· '	**	$\Omega_c^{(3123)}$	$1/2^{+}$	***	$P_{c}(4312)^{+}$		*
N(2250)		****	<i>N</i> (1380)	$1/2^{-}$	*ok	$\Sigma(2455)$		*		3/2+	***	$P_c(4312)^+$ $P_c(4380)^+$		*
N(2300)		**	A(1405)	$1/2^{-}$	****	$\Sigma(2620)$		*	$\Omega_c(2770)^0$	3/2 '	***			*
N(2570)		**	A(1520)	3/2-	****	Σ(3000)		*	$\Omega_{c}(3000)^{0}$		***	$P_c(4440)^+$ $P_c(4457)^+$		*
N(2600)	11/2- 3	***	A(1600)	$1/2^{+}$	****	Σ(3170)		*	$\Omega_{c}(3050)^{0}$		***	FC(4437)		
N(2700)	13/2+ 3		A(1670)	1/2-	****	( )			$\Omega_{c}(3065)^{0}$		***			
( )	/		A(1690)	3/2-	****	<u>=</u> 0	$1/2^{+}$	****	$\Omega_{c}(3090)^{0}$		***			
			A(1710)	1/2+	*	Ξ-	1/2+	****	$\Omega_{c}(3120)^{0}$		4.4.4.			
			A(1800)	$1/2^{-}$	***	<i>Ξ</i> (1530)	3/2+	****	-+		*			
			A(1810)	1/2+	***	$\Xi(1620)$	· '	*	$=_{cc}^{+}$		***			
			A(1820)		****	<i>Ξ</i> (1690)		***	$\equiv_{cc}^{++}$		- Property			
			A(1830)	5/2-	****	<u>=(1820)</u>	3/2-	***						
			A(1890)	3/2+	****	<b>E</b> (1950)		***						
			A(2000)	$1/2^{-}$	*	$\Xi(2030)$	$\geq \frac{5}{2}$ ?	***						
			A(2050)	3/2-	*	Ξ(2120)	- 2	*						
			A(2070)	3/2+	*	<u>=(2250)</u>		**						
			A(2080)	5/2-	*	Ξ(2370)		**						
			A(2085)	7/2+	**	$\Xi(2500)$		*						
			A(2100)	7/2-	****	-(2000)								
			A(2110)		***	$\Omega^{-}$	$3/2^{+}$	****	1					
			A(2325)	3/2-	*	Ω(2012			-					
			A(2350)		***		_		•					
			A(2585)	5/2	*	Ω(238	_1	7	0 k	12	<b>K</b>	IN	ור	<u> </u>
			. (2000)			Ω(2470			VL	10		<b>VUI</b>	10	
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		LIGHT UNI(S = C =			STRAM ( $S = \pm 1, C$		CHARMED, S ( $C = \pm 1$ , S		c <del>c</del> con	$P^{(P^{C})}$
		$P(\hat{f}^{C})$		$I^{G}(J^{PC})$		1(P)	(+ possibly nor	1-qq states)	<ul> <li>ψ<sub>2</sub>(3823)</li> </ul>	0-(2)
	• $\pi^{\pm}$	1-(0-)	<ul> <li>π<sub>2</sub>(1670)</li> </ul>	$1^{-}(2^{-+})$	• K <sup>±</sup>	1/2(0-)		I(f)	<ul> <li>ψ<sub>2</sub>(3842)</li> </ul>	0-(3)
	• $\pi^0$	$1^{-}(0^{-+})$	<ul> <li>φ(1680)</li> </ul>	$0^{-}(1^{-}-)$	• K <sup>0</sup>	1/2(0-)	• D_{S}^{\pm}	0(0_)	χ <sub>c0</sub> (3860)	$0^{+}(0^{+}+)$
	• η	0+(0-+)	<ul> <li>         ρ<sub>3</sub>(1690)     </li> </ul>	1+(3)	• KS	1/2(0-)	<ul> <li>D<sup>*±</sup><sub>S</sub></li> </ul>	0(??)	• χ <sub>c1</sub> (3872)	$0^{+}(1^{++})$
	<ul> <li>f<sub>0</sub>(500)</li> </ul>	$0^+(0^{++})$	<ul> <li>ρ(1700)</li> </ul>	1+(1)	• K2	1/2(0-)	<ul> <li>D<sup>*</sup><sub>50</sub>(2317)<sup>±</sup></li> </ul>	0(0+)	• Z <sub>c</sub> (3900)	$1^+(1^+)$
	• ρ(770)	1+(1)	• a <sub>2</sub> (1700)	$1^{-(2^{++})}$	• K <sub>0</sub> (700)	1/2(0+)	• D <sub>51</sub> (2460) <sup>±</sup>	$0(1^+)$	• χ <sub>c0</sub> (3915)	0+(0++)
	• ω(782)	0-(1)	• f <sub>0</sub> (1710)	$0^{+}(0^{+})$	• K*(892)	1/2(1-)	• D <sub>51</sub> (2536) <sup>±</sup>	$0(1^+)$	• χ <sub>c2</sub> (3930)	$0^+(2^{++})$ $?^?(???)$
	<ul> <li>η'(958)</li> <li>ε (000)</li> </ul>	$0^{+}(0^{-+})$	X(1750)	$?^{-}(1^{-})$	• K <sub>1</sub> (1270)	1/2(1+)	• D <sup>*</sup> <sub>52</sub> (2573)	0(2+)	X(3940)	$1^{+}(?^{?-})$
	<ul> <li>f<sub>0</sub>(980)</li> <li>a₀(980)</li> </ul>	$0^+(0^++)$ $1^-(0^++)$	η(1760) • π(1800)	$0^{+}(0^{-+})$ $1^{-}(0^{-+})$	• K <sub>1</sub> (1400)	1/2(1+)	$D_{s0}(2590)^+$	$0(0^{-})$	<ul> <li>X(4020)<sup>±</sup></li> <li>ψ(4040)</li> </ul>	$0^{-}(1^{-})$
	<ul> <li>φ(1020)</li> </ul>	$0^{-}(1^{-})$	f <sub>2</sub> (1810)	$0^+(2^{++})$	• K*(1410)	$\frac{1/2(1^{-})}{1/2(0^{+})}$	<ul> <li>D<sup>*</sup><sub>\$1</sub>(2700)<sup>±</sup></li> <li>D<sup>*</sup><sub>\$1</sub>(2960)<sup>±</sup></li> </ul>	$0(1^{-})$ $0(1^{-})$	X(4050) <sup>±</sup>	$1^{-}(?^{+})$
	• h1(1170)	$0^{-}(1^{+})$	X(1835)	?(0-+)	• K <sub>0</sub> (1430) • K <sub>2</sub> (1430)	$1/2(0^+)$ $1/2(2^+)$	$D_{S1}^*(2860)^{\pm}$ • $D_{S3}^*(2860)^{\pm}$	0(1)	$X(4055)^{\pm}$	1+(??-)
	<ul> <li>b1(1235)</li> </ul>	1+(1+-)	<ul> <li>φ<sub>3</sub>(1850)</li> </ul>	0-(3)	• K(1460)	$1/2(2^{-1})$ $1/2(0^{-1})$	$X_0(2900)$	?(0 <sup>+</sup> )	X(4100) <sup>±</sup>	$1^{-}(?^{??})$
	<ul> <li>a1(1260)</li> </ul>	$1^{-(1++)}$	<ul> <li>η<sub>2</sub>(1870)</li> </ul>	$0^{+}(2^{-}+)$	K <sub>2</sub> (1580)	$1/2(0^{-})$	$X_0(2900)$ $X_1(2900)$	?(1-)	• χ <sub>c1</sub> (4140)	$0^{+(1^{++})}$
	<ul> <li>f<sub>2</sub>(1270)</li> </ul>	$0^{+}(2^{++})$	<ul> <li>π<sub>2</sub>(1880)</li> </ul>	$1^{-}(2^{-+})$	K(1630)	1/2(??)	$D_{sJ}(3040)^{\pm}$	0(??)	<ul> <li>ψ(4160)</li> </ul>	$0^{-}(1^{-})$
	<ul> <li>f<sub>1</sub>(1285)</li> </ul>	$0^{+}(1^{++})$	$\rho(1900)$	1+(1)	• K1(1650)	1/2(1+)		. ,	X(4160)	? <sup>?</sup> (? <sup>?</sup> ?)
	<ul> <li>η(1295)</li> </ul>	$0^{+}(0^{-}+)$	$f_2(1910)$	0+(2++)	• K*(1680)	1/2(1-)	BOTT (B = ±		$Z_c(4200)$	$1^{+}(1^{+})$
	<ul> <li>π(1300)</li> <li>π(1300)</li> </ul>	$1^{-}(0^{-+})$	$a_0(1950)$	$1^{-}(0^{++})$	• K <sub>2</sub> (1770)	1/2(2-)	• B <sup>±</sup>		<ul> <li>ψ(4230)</li> <li>R = (4240)</li> </ul>	$0^{-}(1^{-})$
	• $a_2(1320)$	$1^{-(2^{++})}_{0^{+}(0^{++})}$	• $f_2(1950)$	$0^{+}(2^{++})$ $1^{-}(4^{++})$	• $K_3^*(1780)$	1/2(3-)	• B <sup></sup>	1/2(0 <sup></sup> ) 1/2(0 <sup></sup> )	$R_{c0}(4240)$ $X(4250)^{\pm}$	$1^{+}(0^{})$ $1^{-}(?^{?+})$
	<ul> <li>f<sub>0</sub>(1370)</li> <li>π<sub>1</sub>(1400)</li> </ul>	$1^{-}(1^{-}+)$	<ul> <li>∂<sub>4</sub>(1970)</li> <li>ρ<sub>3</sub>(1990)</li> </ul>	$1^{+}(3^{-})$	• $K_2(1820)$	1/2(2-)	• B±/B <sup>0</sup> ADN		• χ <sub>C1</sub> (4274)	$0^{+}(1^{++})$
	• η(1405)	$0^{+}(0^{-}+)$	$\pi_2(2005)$	$1^{-}(2^{-}+)$	K(1830)	1/2(0 <sup>-</sup> )	<ul> <li>B<sup>±</sup>/B<sup>0</sup>/B<sup>0</sup></li> </ul>		X(4350)	0+(??+)
	<ul> <li>h1(1415)</li> </ul>	$0^{-}(1^{+})$	• f5(2010)	$0^{+}(2^{+}+)$	$K_0(1950)$	$1/2(0^+)$	ADMIXTŰŔ	E	<ul> <li>ψ(4360)</li> </ul>	$0^{-}(1^{-})$
	• f1(1420)	0+(1++)	f <sub>0</sub> (2020)	$0^{+}(0^{+}+)$	• K <sub>2</sub> (1980) • K <sub>4</sub> (2045)	$1/2(2^+)$ $1/2(4^+)$	V <sub>cb</sub> and V <sub>ub</sub> trix Elements		<ul> <li>ψ(4415)</li> </ul>	$0^{-(1^{-})}$
	<ul> <li>ω(1420)</li> </ul>	$0^{-}(1^{-})$	<ul> <li>f<sub>4</sub>(2050)</li> </ul>	$0^{+}(4^{++})$	$K_{2}(2043)$ $K_{2}(2250)$	$1/2(4^{-1})$ $1/2(2^{-1})$	• B*	1/2(1-)	• Z <sub>c</sub> (4430)	$1^{+}(1^{+-})$
	$f_2(1430)$	$0^{+}(2^{++})$	π <sub>2</sub> (2100)	1-(2-+)	K <sub>3</sub> (2320)	1/2(2)	• B <sub>1</sub> (5721)	$1/2(1^+)$	χ <sub>c0</sub> (4500)	0+(0++)
	• a <sub>0</sub> (1450)	$1^{-}(0^{++})$	f <sub>0</sub> (2100)	0+(0++)	K <sub>5</sub> (2380)	1/2(5-)	B <sup>*</sup> <sub>J</sub> (5732)	?(??)	X(4630)	0+(??+)
	<ul> <li>         ρ(1450)         </li> </ul>	$1^+(1^{})$	$f_2(2150)$	$0^+(2^{++})$	K4(2500)	1/2(4-)	<ul> <li>B<sup>*</sup><sub>2</sub>(5747)</li> </ul>	$1/2(2^+)$	<ul> <li>ψ(4660)</li> </ul>	$0^{-}(1^{-})$
	<ul> <li>η(1475)</li> <li>(1500)</li> </ul>	$0^+(0^{-+})$ $0^+(0^{++})$	$\rho(2150)$	$1^{+}(1^{-})$ $0^{-}(1^{-})$	K(3100)	( <sup>??</sup> ,) <sup>?</sup> ?	BJ(5840)	1/2(??)	$\chi_{c1}(4685)$	$0^+(1^{++})$ $0^+(0^{++})$
	<ul> <li>f<sub>0</sub>(1500)</li> <li>f<sub>1</sub>(1510)</li> </ul>	$0^{+}(0^{+})^{+}(1^{+})$	<ul> <li>φ(2170)</li> <li>f<sub>0</sub>(2200)</li> </ul>	$0^{+}(0^{+}+)$	CHARM	455	• <i>B</i> J(5970)	1/2(??)	<sub>χc0</sub> (4700)	0.(0)
	• f'_2(1525)	$0^{+}(2^{+})$	$f_{l}(2220)$	0+(2++)	(C = :		BOTTOM, S	TRANGE	b	Б
	f2(1565)	$0^{+}(2^{+}+)$	1)(2220)	ar 4 + +)	• D <sup>±</sup>	1/2(0-)	$(B = \pm 1, 5)$		(+ possibly no	on qq states)
	p(1570)	1+(1)	$\eta(2225)$	$0^{+}(0^{-}+)$	• D <sup>0</sup>	$1/2(0^{-})$ $1/2(0^{-})$	• B <sup>0</sup> <sub>5</sub>	0(0-)	<ul> <li>η<sub>b</sub>(1S)</li> </ul>	0+(0-+)
	h1(1595)	$0^{-}(1^{+})$	ρ <sub>3</sub> (2250)	1+(3)	<ul> <li>D*(2007)<sup>0</sup></li> </ul>	1/2(1-)	• B <sup>*</sup> <sub>s</sub>	$0(1^{-})$	<ul> <li> <i>Υ</i>(15)     </li> </ul>	0-(1)
	<ul> <li>π<sub>1</sub>(1600)</li> </ul>	$1^{-}(1^{-}+)$	• f <sub>2</sub> (2300)	0+(2++)	• D*(2010) <sup>±</sup>	1/2(1-)	X(5568)±	?(??)	<ul> <li>         χ<sub>b0</sub>(1P)     </li> </ul>	0+(0++)
	• a <sub>1</sub> (1640)	$1^{-}(1^{++})$	f <sub>4</sub> (2300)	0+(4++)	<ul> <li>D<sub>0</sub>(2300)</li> </ul>	1/2(0+)	<ul> <li>B<sub>s1</sub>(5830)<sup>0</sup></li> </ul>	$0(1^+)$	<ul> <li>         χ<sub>b1</sub>(1P)     </li> </ul>	$0^{+}(1^{+})$
	$f_2(1640)$	$0^+(2^{++})$	f <sub>0</sub> (2330)	0+(0++)	• D <sub>1</sub> (2420)	$1/2(1^+)$	<ul> <li>B<sup>*</sup><sub>52</sub>(5840)<sup>0</sup></li> </ul>	0(2+)	<ul> <li>h<sub>b</sub>(1P)</li> <li>(1D)</li> </ul>	$0^{-}(1^{+})^{-})$ $0^{+}(2^{+})^{+})$
	<ul> <li>η<sub>2</sub>(1645)</li> </ul>	$0^{+}(2^{-+})$	• f <sub>2</sub> (2340)	$0^+(2^{++})$	<ul> <li>D<sub>1</sub>(2430)<sup>0</sup></li> </ul>	1/2(1+)	$B_{sJ}^{*}(5850)$	?(??)	• $\chi_{b2}(1P)$ $\eta_b(2S)$	$0^{+}(0^{-}+)$
	<ul> <li>ω(1650)</li> <li>(1670)</li> </ul>		ρ <sub>5</sub> (2350)	$\frac{1^{+}(5^{-})}{??(??)}$	• D <sub>2</sub> (2460)	1/2(2+)	$B_{sJ}(6063)^0$	0(??)	• Υ(25)	$0^{-}(1^{-})$
	<ul> <li>ω<sub>3</sub>(167<sup>ex</sup>)</li> </ul>		X(2370) 2510)	0+(6++)	$D_0(2550)^0$	1/2(0-)	$B_{sJ}(6114)^0$	0(??)	<ul> <li> <i>γ</i><sub>2</sub>(1D)     </li> </ul>	$0^{-}(2^{-})$
			-510)	0.(0)	D* (2600) <sup>0</sup>	1/2(1-)	BOTTOM, C	HARMED	<ul> <li>         χ<sub>b0</sub>(2P)     </li> </ul>	0+(0++)
					D*(2640)±	1/2(??)	(B = C =		<ul> <li>         χ<sub>b1</sub>(2P)     </li> </ul>	$0^{+}(1^{++})$
					$D_2(2740)^0$	$1/2(2^{-})$	• B_c^+	0(0-)	<ul> <li>h<sub>b</sub>(2P)</li> </ul>	$0^{-(1+-)}$
					• D <sub>3</sub> (2750)	1/2(3 <sup></sup> ) 1/2(1 <sup></sup> )	<ul> <li>         • B<sub>c</sub>(2S)<sup>±</sup> </li> </ul>	0(0-)	• χ <sub>b2</sub> (2P)	0+(2++)
					$D_1(2760)^0$ $D(3000)^0$	1/2(1)	c <del>c</del>		• T(35)	0-(1)
					2(200)	1/2(.)	сс (+ possibly nor	-aa states)	<ul> <li>χ<sub>b1</sub>(3P)</li> </ul>	$0^{+}(1^{+})^{+}$ $0^{+}(2^{+})^{+}$
									• χ <sub>b2</sub> (3P)	
							<ul> <li>η<sub>c</sub>(1S)</li> </ul>	0+(0 - +)	<ul> <li>         Υ(45)         </li> </ul>	0-(1)
							<ul> <li>η<sub>c</sub>(1S)</li> <li>J/ψ(1S)</li> </ul>	$0^{+}(0^{-}+)$ $0^{-}(1^{-}-)$	<ul> <li> Υ(45) </li> <li> <i>Z<sub>b</sub></i>(10610) </li> </ul>	$0^{-(1^{-})}_{1^{+}(1^{+})}$
							<ul> <li>η<sub>c</sub>(1S)</li> <li>J/ψ(1S)</li> <li>(1P)</li> <li>(1P)</li> </ul>	$0^{+}(0^{-}+)$ $0^{-}(1^{-}-)$ $0^{+}(0^{+}+)$	• $\Upsilon(4S)$ • $Z_b(10610)$ • $Z_b(10650)$	$0^{-(1^{-})}$ $1^{+(1^{+})}$ $1^{+(1^{+})}$
		01	0.			5	<ul> <li>η<sub>c</sub>(1S)</li> <li>J/ψ(1S)</li> <li>(1P)</li> <li>(1P)</li> </ul>	$0^{+}(0^{-}+)$ $0^{-}(1^{-}-)$	<ul> <li> Υ(45) </li> <li> <i>Z<sub>b</sub></i>(10610) </li> </ul>	$0^{-(1^{-})}_{1^{+}(1^{+})}$
	~	21	0	me	eso	n	• $\eta_c(1S)$ • $J/\psi(1S)$ (1P) (1P) 1P) (1P) (1P)	$0^+(0^{-+})$ $0^-(1^{})$ $0^+(0^{++})$ $0^+(1^{++})$ $0^-(1^{+-})$ $0^+(2^{++})$	• $\Upsilon(4S)$ • $Z_b(10610)$ • $Z_b(10650)$ $\Upsilon(10753)$	$0^{-(1^{-})}$ $1^{+(1^{+})}$ $1^{+(1^{+})}$ $?^{?}(1^{-})$
	~	21	0	me	eso	n	• η <sub>c</sub> (15) • J/ψ(15) (1P) (1P) 1P) (1P) 2S)		• $\Upsilon(45)$ • $Z_b(10610)$ • $Z_b(10650)$ $\Upsilon(10753)$ • $\Upsilon(10860)$ • $\Upsilon(11020)$	$\begin{array}{c} 0^{-}(1^{-}) \\ 1^{+}(1^{+}) \\ 1^{+}(1^{+}) \\ ?^{?}(1^{-}) \\ 0^{-}(1^{-}) \\ 0^{-}(1^{-}) \end{array}$
	~	21	0 1	me	eso	n	• η <sub>c</sub> (1S) • J/ψ(1S) (1P) (1P) 1P) (1P) 2S) S)	$0^+(0^{-+})$ $0^-(1^{})$ $0^+(0^{++})$ $0^+(1^{++})$ $0^-(1^{+-})$ $0^+(2^{++})$	• $\Upsilon(45)$ • $Z_b(10610)$ • $Z_b(10650)$ $\Upsilon(10753)$ • $\Upsilon(10860)$	$\begin{array}{c} 0^{-}(1^{-}-) \\ 1^{+}(1^{+}-) \\ 1^{+}(1^{+}-) \\ ?^{?}(1^{-}-) \\ 0^{-}(1^{-}-) \\ 0^{-}(1^{-}-) \end{array}$

Most of hadrons are unstable (above two-hadron threshold)

## Aim of this talk

### Various excitations of hadrons



### **Issues:**

- Quantitative discussion of internal structure
- Unstable nature of excited hadrons

#### Contents

## Contents

## Introduction: structure of excited hadrons

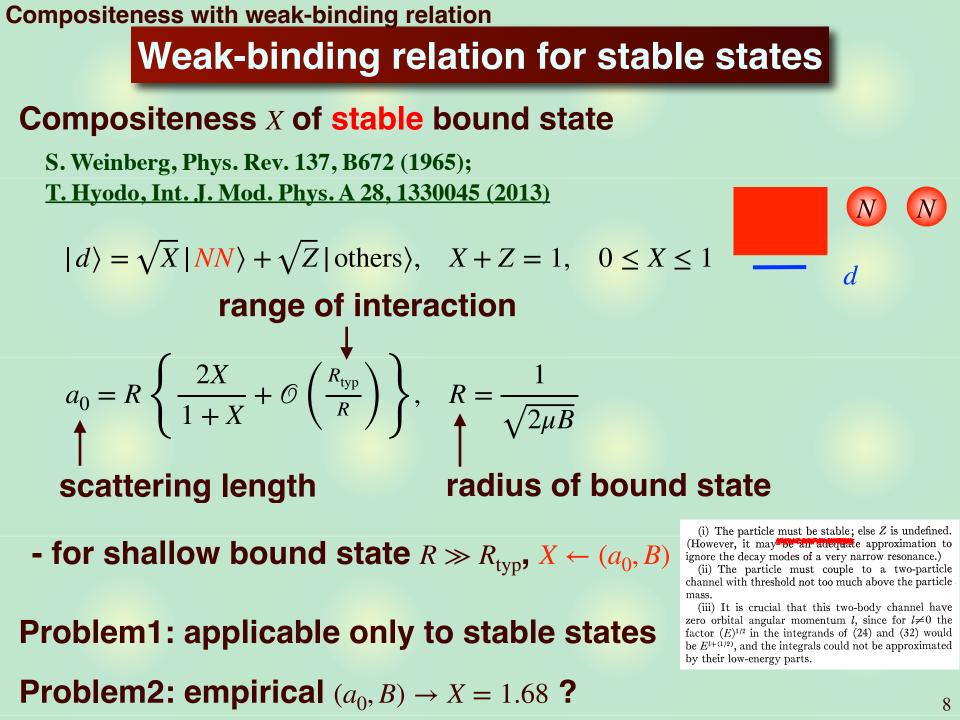
## Compositeness with weak-binding relation

S. Weinberg, Phys. Rev. 137, B672 (1965); <u>T. Hyodo, Int. J. Mod. Phys. A 28, 1330045 (2013);</u> <u>Y. Kamiya, T. Hyodo, PRC93, 035203 (2016); PTEP2017, 023D02 (2017)</u> <u>T. Kinugawa, T. Hyodo, PRC106, 015205 (2022)</u>

## **Compositeness of baryon resonances**

<u>T. Sekihara, T. Hyodo, D. Jido, PTEP2015, 063D04 (2015);</u> T. Sekihara, T. Arai, J. Yamagata-Sekihara, S. Yasui, PRC93, 035204 (2016)





#### Compositeness with weak-binding relation

## **Uncertainty and interpretation**

<u>205 (2022)</u>

 $\leq X \leq 1$ 

### **Uncertainty estimation with** $\mathcal{O}(R_{typ}/R)$ **term**

**Y. Kamiya, T. Hyodo, PTEP2017, 023D02 (2017)** 

$$X_{\rm u} = \frac{a_0/R + \xi}{2 - a_0/R - \xi}, \quad X_{\rm l} = \frac{a_0/R - \xi}{2 - a_0/R + \xi}, \quad \xi = \frac{R_{\rm typ}}{R}$$

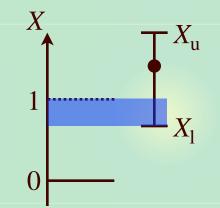
### Interpretation (with finite range correction)

 $R_{\rm typ} = \max\{R_{\rm int}, R_{\rm eff}\}$ 

- *X* of hadrons, nuclei, and atoms
- X of deuteron is reasonable
- $X \ge 0.5$  in all cases studied

### Near-threshold bound states are mostly composite

Bound state	Compositeness X
d	$0.74 \leqslant X \leqslant 1$
X(3872)	$0.53 \leqslant X \leqslant 1$
$D_{s0}^{*}(2317)$	$0.81 \leqslant X \leqslant 1$
$D_{s1}(2460)$	$0.55 \leqslant X \leqslant 1$
$N\Omega$ dibaryon	$0.80 \leqslant X \leqslant 1$
$\Omega\Omega$ dibaryon	$0.79 \leqslant X \leqslant 1$
$^{3}_{\Lambda}$ H	$0.74 \leqslant X \leqslant 1$
<sup>4</sup> He dimer	$0.93 \leqslant X \leqslant 1$



### Compositeness with weak-binding relation Weak-binding relation for unstable states

### **Compositeness** *X* **of unstable** quasibound state

Y. Kamiya, T. Hyodo, PRC93, 035203 (2016); PTEP2017, 023D02 (2017)

- complex eigenenergy:  $-B \rightarrow E_h \in \mathbb{C}$
- $|\Lambda(1405)\rangle = \sqrt{X} |\bar{K}N\rangle + \sqrt{Z} |\text{ others}\rangle, \quad X + Z = 1$ - complex  $a_0, X$

$$\left( \left| \frac{R_{\text{typ}}}{2} \right| \right) + O\left( \left| \frac{\ell}{2} \right|^3 \right) \right) \qquad R - \frac{1}{2} \qquad \ell = \frac{1}{2}$$

$$a_0 = R \left\{ \frac{2X}{1+X} + \mathcal{O}\left( \left| \frac{R_{\text{typ}}}{R} \right| \right) + \mathcal{O}\left( \left| \frac{\ell}{R} \right|^3 \right) \right\}, \quad R = \frac{1}{\sqrt{-2\mu E_h}}, \quad \ell \equiv \frac{1}{\sqrt{2\mu\nu}}$$

- correction from threshold energy difference
- for near-threshold quasibound state  $|R| \gg (R_{typ}, \mathcal{C}), X \leftarrow (a_0, E_h)$ Interpretation of complex *X*

$$\tilde{X} = \frac{1 - |Z| + |X|}{2}, \quad \tilde{Z} = \frac{1 - |X| + |Z|}{2}, \quad \tilde{X} + \tilde{Z} = 1, \quad 0 \le \tilde{X} \le 1$$

 $\Lambda(1405)$ 

#### Compositeness with weak-binding relation

## **Compositeness of** $\Lambda(1405)$ : central values

**Generalized weak-binding relation** 

$$a_0 = R \left\{ \frac{2X}{1+X} + \mathcal{O}\left( \left| \frac{R_{\text{typ}}}{R} \right| \right) + \mathcal{O}\left( \left| \frac{\ell}{R} \right|^3 \right) \right\}, \quad R = \frac{1}{\sqrt{-2\mu E_h}}, \quad \ell \equiv \frac{1}{\sqrt{2\mu E_h}},$$

 $(a_0, E_h)$  determinations by several groups

### - Neglecting correction terms:

	$E_h$ [MeV]	$a_0$ [fm]	$X_{ar{K}N}$	$ ilde{X}_{ar{K}N}$	<i>U</i> /2
Set 1 [35]	-10 - i26	1.39 - i0.85	1.2 + i0.1	1.0	0.3
Set 2 [36]	-4-i8	1.81 - i0.92	0.6 + i0.1	0.6	0.0
Set 3 [37]	-13 - i20	1.30 - i0.85	0.9 - i0.2	0.9	0.1
Set 4 [38]	2 - i10	1.21 - i1.47	0.6 + i0.0	0.6	0.0
Set 5 [38]	-3-i12	1.52 - i1.85	1.0 + i0.5	0.8	0.3

- In all cases,  $X \sim 1$  and  $\tilde{X} \sim 1$ 

### $\Lambda(1405)$ : $\bar{K}N$ composite dominance <- observables

U.1)

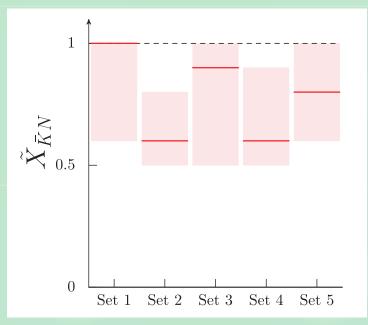
Compositeness with weak-binding relation

## **Compositeness of** $\Lambda(1405)$ : uncertainties

**Estimation of correction terms:**  $|R| \sim 2 \text{ fm}$ 

$$a_0 = R \left\{ \frac{2X}{1+X} + \mathcal{O}\left( \left| \frac{R_{\text{typ}}}{R} \right| \right) + \mathcal{O}\left( \left| \frac{\ell}{R} \right|^3 \right) \right\}, \quad R = \frac{1}{\sqrt{-2\mu E_h}}, \quad \ell \equiv \frac{1}{\sqrt{2\mu\nu}}$$

- $\rho$  meson exchange picture:  $R_{typ} \sim 0.25$  fm
- Energy difference from  $\pi\Sigma$ :  $\ell \sim 1.08 \text{ fm}$



 $\bar{K}N$  composite dominance holds even with correction terms  $_{12}$ 

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#### Compositeness of baryon resonances

## Two methods to evaluate compositeness

## **Weak-binding relation**

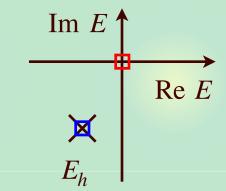
$$a_0 = R \left\{ \frac{2X}{1+X} + \mathcal{O}\left( \left| \frac{R_{\text{typ}}}{R} \right| \right) + \mathcal{O}\left( \left| \frac{\ell}{R} \right|^3 \right) \right\}, \quad R = \frac{1}{\sqrt{-2\mu E_h}}, \quad \ell \equiv \frac{1}{\sqrt{2\mu\nu}}$$

- Pro: model independent, determined by observables
- Con: uncertainty, near-threshold s-wave state only

### **Evaluation from residue of resonance pole**

<u>T. Hyodo, D. Jido, A. Hosaka, PRC85, 015201 (2012);</u> F. Aceti. E. Oset, PRD86, 014012 (2012)

$$X = -g^2 \frac{dG(E)}{dE} \bigg|_{E=E_h}$$



- Pro: no uncertainty, applicable to any states (e.g. p wave)
- Con: model dependent (off-shell nature)

### Two methods are complementary with each other

#### Compositeness of baryon resonances

## **Comparison of two methods**

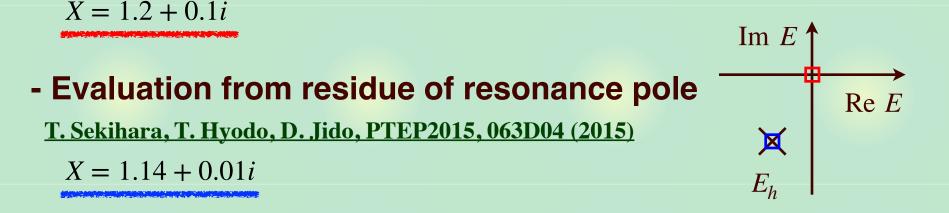
## **Compositeness of** $\Lambda(1405)$ with NLO chiral SU(3) dynamics

Y. Ikeda, T. Hyodo, W. Weise, PLB 706, 63 (2011); NPA881, 98 (2012)

 $E_h = -10 - 26i$  [MeV]

### - Weak-binding relation

Y. Kamiya, T. Hyodo, PRC93, 035203 (2016); PTEP2017, 023D02 (2017)



Good agreement <—  $\Lambda(1405)$  is sufficiently close to threshold

### - model dependence/uncertainty reduces as $|E_h| \rightarrow 0$

see also T. Kinugawa, T. Hyodo, arXiv:2303.07038 [hep-ph]

#### Compositeness of baryon resonances

## **Compositeness of baryon resonances**

## Unitarized NLO cihral (coupled-channel) amplitude

T. Sekihara, T. Arai, J. Yamagata-Sekihara, S. Yasui, PRC93, 035204 (2016)

	Naive		Constrained			
	Δ(1232)	N(940)	Δ(1232)	N(940)		
$\overline{w_{\text{pole}}}$ (MeV)	1209.8 – 47.6 <i>i</i>	938.9	1206.9 – 49.6 <i>i</i>	938.9		
$g(MeV^{-1/2})$	0.383 - 0.053i	0.560	0.395 - 0.061i	0.516		
$X_{\pi N}$	0.69 + 0.39i	-0.18	0.87 + 0.35i	0.00		
Ζ	0.31 - 0.39i	1.18	0.13 - 0.35i	1.00		
U	0.30	_	0.31	_		
$\tilde{X}_{\pi N}$	0.61	_	0.71	_		
Ĩ	0.39	_	0.29	_		

	1	
	N(1535)	N(1650)
$\overline{w_{\text{pole}}}$ (MeV)	1496.4 – 58.7 <i>i</i>	1660.7 - 70.0i
$g_{\pi N}$ (MeV <sup>1/2</sup> )	47.1 - 7.3i	49.8 - 23.1i
$g_{\eta N} ({\rm MeV}^{1/2})$	68.9 - 42.4i	-19.0 + 11.1i
$g_{K\Lambda}$ (MeV <sup>1/2</sup> )	85.0 + 14.4i	-29.9 + 37.1i
$g_{K\Sigma}$ (MeV <sup>1/2</sup> )	-31.4 + 17.5i	-73.8 + 6.0i
$X_{\pi N}$	-0.02 + 0.03i	0.00 + 0.04i
$X_{\eta N}$	0.04 + 0.37i	0.00 + 0.01i
$X_{K\Lambda}$	0.14 + 0.00i	0.08 + 0.05i
$X_{K\Sigma}$	0.01 - 0.02i	0.09 - 0.12i
Ζ	0.84 - 0.38i	0.84 + 0.01i
U	0.48	0.13
$ ilde{X}_{\piN}$	0.03	0.04
$ ilde{X}_{\eta N}$	0.25	0.01
$ ilde{X}_{K\Lambda}$	0.09	0.08
$ ilde{X}_{K\Sigma}$	0.01	0.13
Ĩ	0.62	0.74

TABLE II. Properties of  $\Delta(1232)$  and N(940). We do not calculate U,  $\tilde{X}_{\pi N}$ , and  $\tilde{Z}$  for N(940) because it is a stable state.

- N(940): Z dominance (qqq like) -  $\Delta(1232)$ :  $X_{\pi N}$  dominance (molecule like)
  - N(1535), N(1650): Z dominance (qqq like)

TABLE IV. Properties of N(1535) and N(1650).

## What to measure

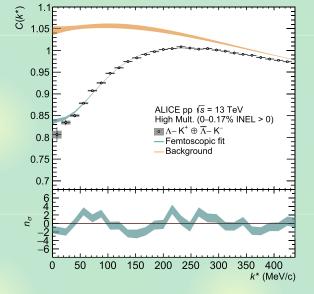
**Determination of (partial wave) scattering amplitude** 

- cross sections, angular dependence, ...
- pole position (eigenenergy) —> weak-binding relation
- dynamical coupled-channel model —> residue method

### **Determination of scattering length**

-  $\Lambda K^+$  scattering length by femtoscopy

$$a_0^{\Lambda K^+} = 0.61 - 0.23i$$
 [fm]



ALICE collaboration, PRC 103, 055201 (2021); PLB 845, 138145 (2023)

### Accumulation of data will sharpen the evaluation of X

#### Summary

## Summary

Structure of hadrons should be studied

- in quantitative manner, and
- with unstable nature taken into account.

**Compositeness is a quantitative measure of hadron structure, applicable to unstable states.** 

- weak-binding relation (model-independent)
- residue method (no uncertainty)

Compositeness of baryon resonances have been evaluated. More experimental data are welcome to improve the estimations.