What is Exotic Hadron ?

D. Jido
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hot topic in hadron physics

two experimental reports in 2003

suggestion of pentaquark state at LEPS

observation of new X(3872) particle at Belle in 2003

cannot be explained by simple qbarq state

more new states coming mainly from B factories

in which a lot of B mesons are produced to study CP violation
at the same time
any hadrons are created from decay of B mesons with high statistics

ex. Zb(10610), Zb(10650) announced on 2012. 1. 10 (press release) by KEK

$ud^{bar}bb^{bar}$

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State	Mass (MeV)	Width (MeV)	Decay	Production
Ys(2175)	2175±8	58±26	ff_0	ISR
X(3872)	3871.84±0.33	<0.95	J/ypp, J/yg	B decay
X(3872)	3872.8 +0.7/-0.6	3.9 +2.8/-1.8	$D^{*0}D^0$	B decay
Z(3940)	3929±5	29±10	DD	gg
X(3940)	3942±9	37±17	DD*	Double-charm
Y(3940)	3942±17	87±34	J/yw	B decay
Y(4008)	4008 +82/-49	226 +97/-80	J/ypp	ISR
$Z(4051)^+$	4051 +24/-43	82 +51/-28	pc_{c1}	B decay
X(4160)	4156±29	139 +113/-65	D*D*	Double-charm
$Z(4248)^+$	4248 +185/-45	177 +320/-72	pc_{c1}	B decay
Y(4260)	4264±12	83±22	J/ypp	ISR
Y(4350)	4361±13	74±18	y'pp	ISR
$Z(4430)^+$	4433±5	45 +35/-18	y'p	B decay
Y(4660)	4664±12	48±15	y'pp	ISR
$Y_b(10890)$	10889.6±2.3	54.7 +8.9/-7.6	ppϒ(nS)	e^+e^- annihilation
Y(3915)	3915±4	17±10	J/yw	gg
X(4350)	4350 +4.7/-5.1	13 +18/-14	J/yf	gg
$h_b(1P)$	9898.3±1.5		MM(pp)	ϒ(5S) /Y_b decay
$h_b(2P)$	10259.3 +1.6/-1.2		MM(pp)	ϒ(5S) /Y_b decay
$Z_b(10610)$	10608.4±2.0	15.6±2.5	(ϒ(nS) or h_b)p	ϒ(5S) /Y_b decay
$Z_b(10650)$	10653.2±1.5	14.4±3.2	(ϒ(nS) or h_b)p	ϒ(5S) /Y_b decay

ex. Zb(10610), Zb(10650) announced on 2012. 1. 10 (press release) by KEK

$ud^{bar}bb^{bar}$

Hadron

hadron: particles interacting by strong interaction

more than 300 hadrons observed, **rich spectra**

meson

LIGHT UNFLAVORED ($S = C = B = 0$)

	$I^G(J^{PC})$		$I^G(J^{PC})$
• $\pi^\pm$	$1^-(0^-)$	• $\pi_2(1670)$	$1^-(2^{-+})$
• π^0	$1^-(0^{-+})$	• $\phi(1680)$	$0^-(1^{--})$
• η	$0^+(0^{-+})$	• $\rho_3(1690)$	$1^+(3^{--})$
• $f_0(600)$	$0^+(0^{++})$	• $\rho(1700)$	$1^+(1^{--})$
• $\rho(770)$	$1^+(1^{--})$	$a_2(1700)$	$1^-(2^{++})$
• $\omega(782)$	$0^-(1^{--})$	• $f_0(1710)$	$0^+(0^{++})$
• $\eta'(958)$	$0^+(0^{-+})$	$\eta(1760)$	$0^+(0^{-+})$
• $f_0(980)$	$0^+(0^{++})$	• $\pi(1800)$	$1^-(0^{-+})$
• $a_0(980)$	$1^-(0^{++})$	$f_2(1810)$	$0^+(2^{++})$
• $\phi(1020)$	$0^-(1^{--})$	• $X(1835)$	$?^?(?^{-+})$
• $h_1(1170)$	$0^-(1^{+-})$	• $\phi_3(1850)$	$0^-(3^{--})$
• $b_1(1235)$	$1^+(1^{+-})$	$\eta_2(1870)$	$0^+(2^{-+})$
• $a_1(1260)$	$1^-(1^{++})$	• $\pi_2(1880)$	$1^-(2^{-+})$
• $f_2(1270)$	$0^+(2^{++})$	$\rho(1900)$	$1^+(1^{--})$
• $f_1(1285)$	$0^+(1^{++})$	$f_2(1910)$	$0^+(2^{++})$
• $\eta(1295)$	$0^+(0^{-+})$	• $f_2(1950)$	$0^+(2^{++})$
• $\pi(1300)$	$1^-(0^{-+})$	$\rho_3(1990)$	$1^+(3^{--})$
• $a_2(1320)$	$1^-(2^{++})$	• $f_2(2010)$	$0^+(2^{++})$
• $f_0(1370)$	$0^+(0^{++})$	$f_0(2020)$	$0^+(0^{++})$
$h_1(1380)$	$?^-(1^{+-})$	• $a_4(2040)$	$1^-(4^{++})$
• $\pi_1(1400)$	$1^-(1^{-+})$	• $f_4(2050)$	$0^+(4^{++})$
• $\eta(1405)$	$0^+(0^{-+})$	$\pi_2(2100)$	$1^-(2^{-+})$
• $f_1(1420)$	$0^+(1^{++})$	$f_0(2100)$	$0^+(0^{++})$
• $\omega(1420)$	$0^-(1^{--})$	$f_2(2150)$	$0^+(2^{++})$
$f_2(1430)$	$0^+(2^{++})$	$\rho(2150)$	$1^+(1^{--})$
• $a_0(1450)$	$1^-(0^{++})$	• $\phi(2170)$	$0^-(1^{--})$
• $\rho(1450)$	$1^+(1^{--})$	$f_0(2200)$	$0^+(0^{++})$
• $\eta(1475)$	$0^+(0^{-+})$	$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$
• $f_0(1500)$	$0^+(0^{++})$		
$f_1(1510)$	$0^+(1^{++})$	$\eta(2225)$	$0^+(0^{-+})$
• $f_2'(1525)$	$0^+(2^{++})$	$\rho_3(2250)$	$1^+(3^{--})$
$f_2(1565)$	$0^+(2^{++})$	• $f_2(2300)$	$0^+(2^{++})$
$\rho(1570)$	$1^+(1^{--})$	$f_4(2300)$	$0^+(4^{++})$
$h_1(1595)$	$0^-(1^{+-})$	$f_0(2330)$	$0^+(0^{++})$
• $\pi_1(1600)$	$1^-(1^{-+})$	• $f_2(2340)$	$0^+(2^{++})$
$a_1(1640)$	$1^-(1^{++})$	$\rho_5(2350)$	$1^+(5^{--})$
$f_2(1640)$	$0^+(2^{++})$	$a_6(2450)$	$1^-(6^{++})$
• $\eta_2(1645)$	$0^+(2^{-+})$	$f_6(2510)$	$0^+(6^{++})$
• $\omega(1650)$	$0^-(1^{--})$	**OTHER LIGHT**	
• $\omega_3(1670)$	$0^-(3^{--})$	Further States	

STRANGE ($S = \pm1$, $C = B = 0$)

	$I(J^P)$
• $K^\pm$	$1/2(0^-)$
• K^0	$1/2(0^-)$
• K^0_S	$1/2(0^-)$
• K^0_L	$1/2(0^-)$
$K_0^*(800)$	$1/2(0^+)$
• $K^*(892)$	$1/2(1^-)$
• $K_1(1270)$	$1/2(1^+)$
• $K_1(1400)$	$1/2(1^+)$
• $K^*(1410)$	$1/2(1^-)$
• $K_0^*(1430)$	$1/2(0^+)$
• $K_2^*(1430)$	$1/2(2^+)$
$K(1460)$	$1/2(0^-)$
$K_2(1580)$	$1/2(2^-)$
$K(1630)$	$1/2(?^?)$
$K_1(1650)$	$1/2(1^+)$
• $K^*(1680)$	$1/2(1^-)$
• $K_2(1770)$	$1/2(2^-)$
• $K_3^*(1780)$	$1/2(3^-)$
• $K_2(1820)$	$1/2(2^-)$
$K(1830)$	$1/2(0^-)$
$K_0^*(1950)$	$1/2(0^+)$
$K_2^*(1980)$	$1/2(2^+)$
• $K_4^*(2045)$	$1/2(4^+)$
$K_2(2250)$	$1/2(2^-)$
$K_3(2320)$	$1/2(3^+)$
$K_5^*(2380)$	$1/2(5^-)$
$K_4(2500)$	$1/2(4^-)$
$K(3100)$	$?^?(?^{??})$

CHARMED ($C = \pm1$)

• $D^\pm$	$1/2(0^-)$
• D^0	$1/2(0^-)$
• $D^*(2007)^0$	$1/2(1^-)$
• $D^*(2010)^\pm$	$1/2(1^-)$
• $D_0^*(2400)^0$	$1/2(0^+)$
$D_0^*(2400)^\pm$	$1/2(0^+)$
• $D_1(2420)^0$	$1/2(1^+)$
$D_1(2420)^\pm$	$1/2(?^?)$
$D_1(2430)^0$	$1/2(1^+)$
• $D_2^*(2460)^0$	$1/2(2^+)$
• $D_2^*(2460)^\pm$	$1/2(2^+)$
$D(2550)^0$	$1/2(0^-)$
$D(2600)$	$1/2(?^?)$
$D^*(2640)^\pm$	$1/2(?^?)$
$D(2750)$	$1/2(?^?)$

CHARMED, STRANGE ($C = S = \pm1$)

	$I(J^P)$
• $D_s^\pm$	$0(0^-)$
• $D_s^{*\pm}$	$0(?^?)$
• $D_{s0}^*(2317)^\pm$	$0(0^+)$
• $D_{s1}(2460)^\pm$	$0(1^+)$
• $D_{s1}(2536)^\pm$	$0(1^+)$
• $D_{s2}(2573)$	$0(?^?)$
$D_{s1}^*(2700)^\pm$	$0(1^-)$
$D_{sJ}^*(2860)^\pm$	$0(?^?)$
$D_{sJ}(3040)^\pm$	$0(?^?)$

BOTTOM ($B = \pm1$)

• $B^\pm$	$1/2(0^-)$
• B^0	$1/2(0^-)$
• $B^\pm/B^0$ ADMIXTURE	
• $B^\pm/B^0/B^0_s/b$-baryon ADMIXTURE	
V_{cb} and V_{ub} CKM Matrix Elements	
• B^*	$1/2(1^-)$
$B_J^*(5732)$	$?(?^?)$
• $B_1(5721)^0$	$1/2(1^+)$
• $B_2^*(5747)^0$	$1/2(2^+)$

BOTTOM, STRANGE ($B = \pm1$, $S = \mp1$)

• B_s^0	$0(0^-)$
• B_s^*	$0(1^-)$
• $B_{s1}(5830)^0$	$0(1^+)$
• $B_{s2}^*(5840)^0$	$0(2^+)$
$B_{sJ}^*(5850)$	$?(?^?)$

BOTTOM, CHARMED ($B = C = \pm1$)

• $B_c^\pm$	$0(0^-)$

$c\bar{c}$

	$I^G(J^{PC})$
• $\eta_c(1S)$	$0^+(0^{-+})$
• $J/\psi(1S)$	$0^-(1^{--})$
• $\chi_{c0}(1P)$	$0^+(0^{++})$
• $\chi_{c1}(1P)$	$0^+(1^{++})$
• $h_c(1P)$	$?^?(1^{+-})$
• $\chi_{c2}(1P)$	$0^+(2^{++})$
• $\eta_c(2S)$	$0^+(0^{-+})$
• $\psi(2S)$	$0^-(1^{--})$
• $\psi(3770)$	$0^-(1^{--})$
• $X(3872)$	$0^?(?^{?+})$
$X(3915)$	$0^+(?^{?+})$
• $\chi_{c2}(2P)$	$0^+(2^{++})$
$X(3940)$	$?^?(?^{??})$
• $\psi(4040)$	$0^-(1^{--})$
$X(4050)^\pm$	$?(?^?)$
$X(4140)$	$0^+(?^{?+})$
• $\psi(4160)$	$0^-(1^{--})$
$X(4160)$	$?^?(?^{??})$
$X(4250)^\pm$	$?(?^?)$
• $X(4260)$	$?^?(1^{--})$
$X(4350)$	$0^+(?^{?+})$
$X(4360)$	$?^?(1^{--})$
• $\psi(4415)$	$0^-(1^{--})$
$X(4430)^\pm$	$?(?^?)$
$X(4660)$	$?^?(1^{--})$

$b\bar{b}$

$\eta_b(1S)$	$0^+(0^{-+})$
• $\Upsilon(1S)$	$0^-(1^{--})$
• $\chi_{b0}(1P)$	$0^+(0^{++})$
• $\chi_{b1}(1P)$	$0^+(1^{++})$
• $\chi_{b2}(1P)$	$0^+(2^{++})$
• $\Upsilon(2S)$	$0^-(1^{--})$
• $\Upsilon(1D)$	$0^-(2^{--})$
• $\chi_{b0}(2P)$	$0^+(0^{++})$
• $\chi_{b1}(2P)$	$0^+(1^{++})$
• $\chi_{b2}(2P)$	$0^+(2^{++})$
• $\Upsilon(3S)$	$0^-(1^{--})$
• $\Upsilon(4S)$	$0^-(1^{--})$
• $\Upsilon(10860)$	$0^-(1^{--})$
• $\Upsilon(11020)$	$0^-(1^{--})$

NON-$q\bar{q}$ CANDIDATES

NON-$q\bar{q}$ CANDIDATES

baryon

p	P_{11}	****
n	P_{11}	****
$N(1440)$	P_{11}	****
$N(1520)$	D_{13}	****
$N(1535)$	S_{11}	****
$N(1650)$	S_{11}	****
$N(1675)$	D_{15}	****
$N(1680)$	F_{15}	****
$N(1700)$	D_{13}	***
$N(1710)$	P_{11}	***
$N(1720)$	P_{13}	****
$N(1900)$	P_{13}	**
$N(1900)$	F_{15}	***
$N(1990)$	F_{17}	**
$N(2080)$	D_{13}	**
$N(2090)$	S_{11}	*
$N(2100)$	P_{11}	*
$N(2190)$	G_{17}	****
$N(2200)$	D_{15}	**
$N(2220)$	H_{19}	****
$N(2250)$	G_{19}	****
$N(2600)$	$I_{1,11}$	***
$N(2700)$	$K_{1,13}$	**

$\Delta(1232)$	P_{33}	****
$\Delta(1600)$	P_{33}	***
$\Delta(1620)$	S_{31}	****
$\Delta(1700)$	D_{33}	****
$\Delta(1750)$	P_{31}	*
$\Delta(1900)$	S_{31}	**
$\Delta(1905)$	F_{35}	****
$\Delta(1910)$	P_{31}	****
$\Delta(1920)$	P_{33}	***
$\Delta(1930)$	D_{35}	***
$\Delta(1940)$	D_{33}	*
$\Delta(1950)$	F_{37}	****
$\Delta(2000)$	F_{35}	**
$\Delta(2150)$	S_{31}	*
$\Delta(2200)$	G_{37}	*
$\Delta(2300)$	H_{39}	**
$\Delta(2350)$	D_{35}	*
$\Delta(2390)$	F_{37}	*
$\Delta(2400)$	G_{39}	**
$\Delta(2420)$	$H_{3,11}$	****
$\Delta(2750)$	$I_{3,13}$	**
$\Delta(2950)$	$K_{3,15}$	**
Λ	P_{01}	****
$\Lambda(1405)$	S_{01}	****
$\Lambda(1520)$	D_{03}	****
$\Lambda(1600)$	P_{01}	***
$\Lambda(1670)$	S_{01}	****
$\Lambda(1690)$	D_{03}	****
$\Lambda(1800)$	S_{01}	***
$\Lambda(1810)$	P_{01}	***
$\Lambda(1820)$	F_{05}	****
$\Lambda(1830)$	D_{05}	****
$\Lambda(1890)$	P_{03}	****
$\Lambda(2000)$		*
$\Lambda(2020)$	F_{07}	*
$\Lambda(2100)$	G_{07}	****
$\Lambda(2110)$	F_{05}	***
$\Lambda(2325)$	D_{03}	*
$\Lambda(2350)$	H_{09}	***
$\Lambda(2585)$		**

Σ^+	P_{11}	****
Σ^0	P_{11}	****
Σ^-	P_{11}	****
$\Sigma(1385)$	P_{13}	****
$\Sigma(1480)$		*
$\Sigma(1560)$		**
$\Sigma(1580)$	D_{13}	*
$\Sigma(1620)$	S_{11}	**
$\Sigma(1660)$	P_{11}	***
$\Sigma(1670)$	D_{13}	****
$\Sigma(1690)$		**
$\Sigma(1750)$	S_{11}	***
$\Sigma(1770)$	P_{11}	*
$\Sigma(1775)$	D_{15}	****
$\Sigma(1840)$	P_{13}	*
$\Sigma(1880)$	P_{11}	**
$\Sigma(1915)$	F_{15}	****
$\Sigma(1940)$	D_{13}	***
$\Sigma(2000)$	S_{11}	*
$\Sigma(2030)$	F_{17}	****
$\Sigma(2070)$	F_{15}	*
$\Sigma(2080)$	P_{13}	**
$\Sigma(2100)$	G_{17}	*
$\Sigma(2250)$		***
$\Sigma(2455)$		**
$\Sigma(2620)$		**
$\Sigma(3000)$		*
$\Sigma(3170)$		*

Ξ^0	P_{11}	****
Ξ^-	P_{11}	****
$\Xi(1530)$	P_{13}	****
$\Xi(1620)$		*
$\Xi(1690)$		***
$\Xi(1820)$	D_{13}	***
$\Xi(1950)$		***
$\Xi(2030)$		***
$\Xi(2120)$		*
$\Xi(2250)$		**
$\Xi(2370)$		**
$\Xi(2500)$		*
Ω^-		****
$\Omega(2250)^-$		***
$\Omega(2380)^-$		**
$\Omega(2470)^-$		**

Λ_c^+	****
$\Lambda_c(2595)^+$	***
$\Lambda_c(2625)^+$	***
$\Lambda_c(2765)^+$	*
$\Lambda_c(2880)^+$	***
$\Lambda_c(2940)^+$	***
$\Sigma_c(2455)$	****
$\Sigma_c(2520)$	***
$\Sigma_c(2800)$	***
Ξ_c^+	***
Ξ_c^0	***
$\Xi_c'^+$	***
$\Xi_c'^0$	***
$\Xi_c(2645)$	***
$\Xi_c(2790)$	***
$\Xi_c(2815)$	***
$\Xi_c(2930)$	*
$\Xi_c(2980)$	***
$\Xi_c(3055)$	**
$\Xi_c(3080)$	***
$\Xi_c(3123)$	*
Ω_c^0	***
$\Omega_c(2770)^0$	***
Ξ_{cc}^+	*
Λ_b^0	***
Σ_b	***
Σ_b^*	***
Ξ_b^0, Ξ_b^-	***
Ω_b^-	***

Normal hadron

hadron:

a composite particle made of quarks held together by the strong force. ---Wikipedia

rich spectrum

- dynamics of 5 (6) species of quarks, up, down, strange, charm, bottom, (top)
- quarks are confined in hadrons
- **complex color dynamics is hidden inside hadrons**
- experimentally observable objects are hadrons
  - understanding hadron spectrum gives basic information of color interaction

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understanding hadron spectrum gives basic information of color interaction

interesting observation

Hadrons are categorized into two families: baryons (made of three quarks) and mesons (made of one quark and one antiquark). ---Wikipedia

baryons are made of three quarks

mesons are made of quark-antiquark pair

quantum numbers of hadrons can be understood by quark model

Quark model

quarks in a confinement potential

observed states can be categorized into QM levels

for the details, fine-tuning is necessary

$$H = 2m_Q + \frac{\vec{p}^2}{m_Q} + S(r) + V(r)$$

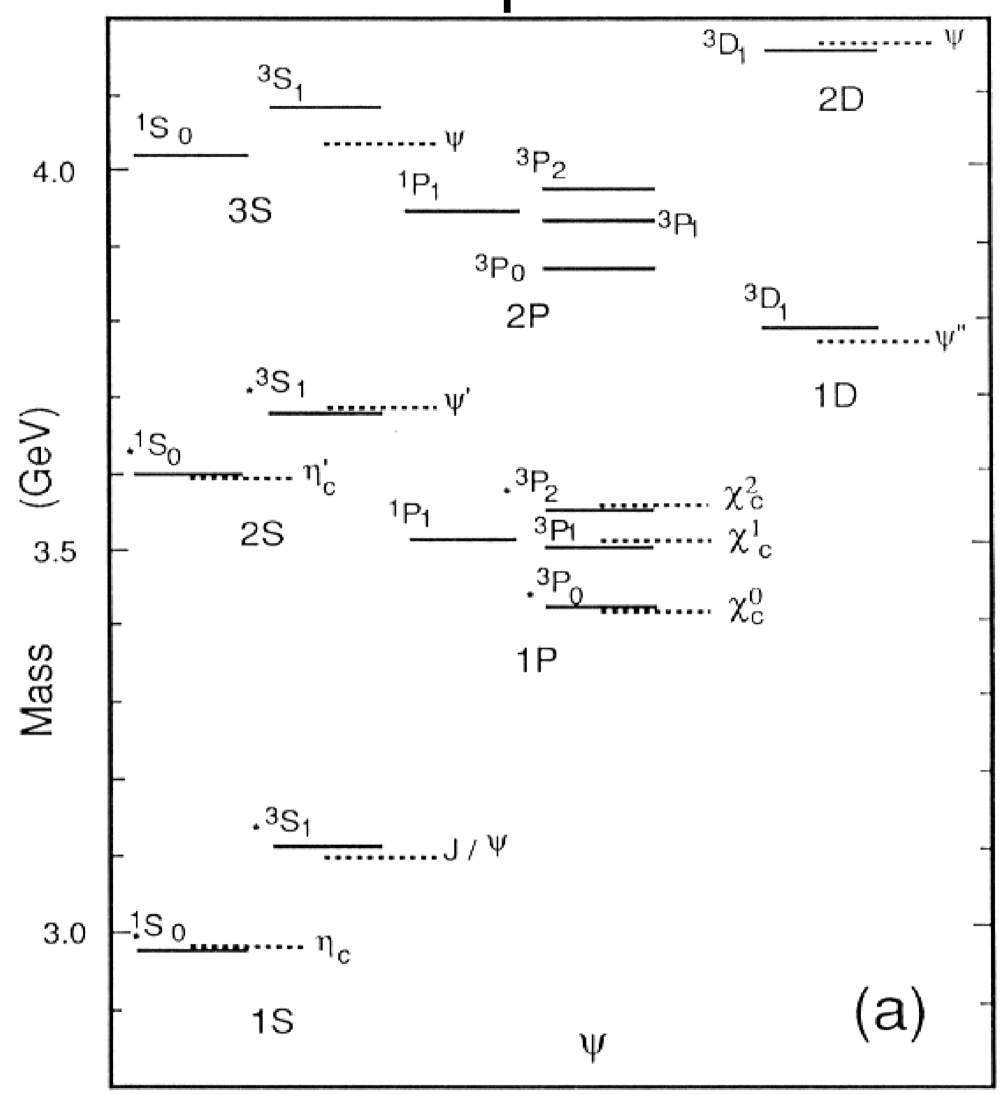
$$S(r) = \sigma r + b$$

$$V(r) = -\frac{4}{3}\frac{\alpha_s(r)}{r} \simeq -\frac{4}{3}\frac{\alpha_s^0}{r}(1 - \exp(-(r/R_c)^\kappa))$$

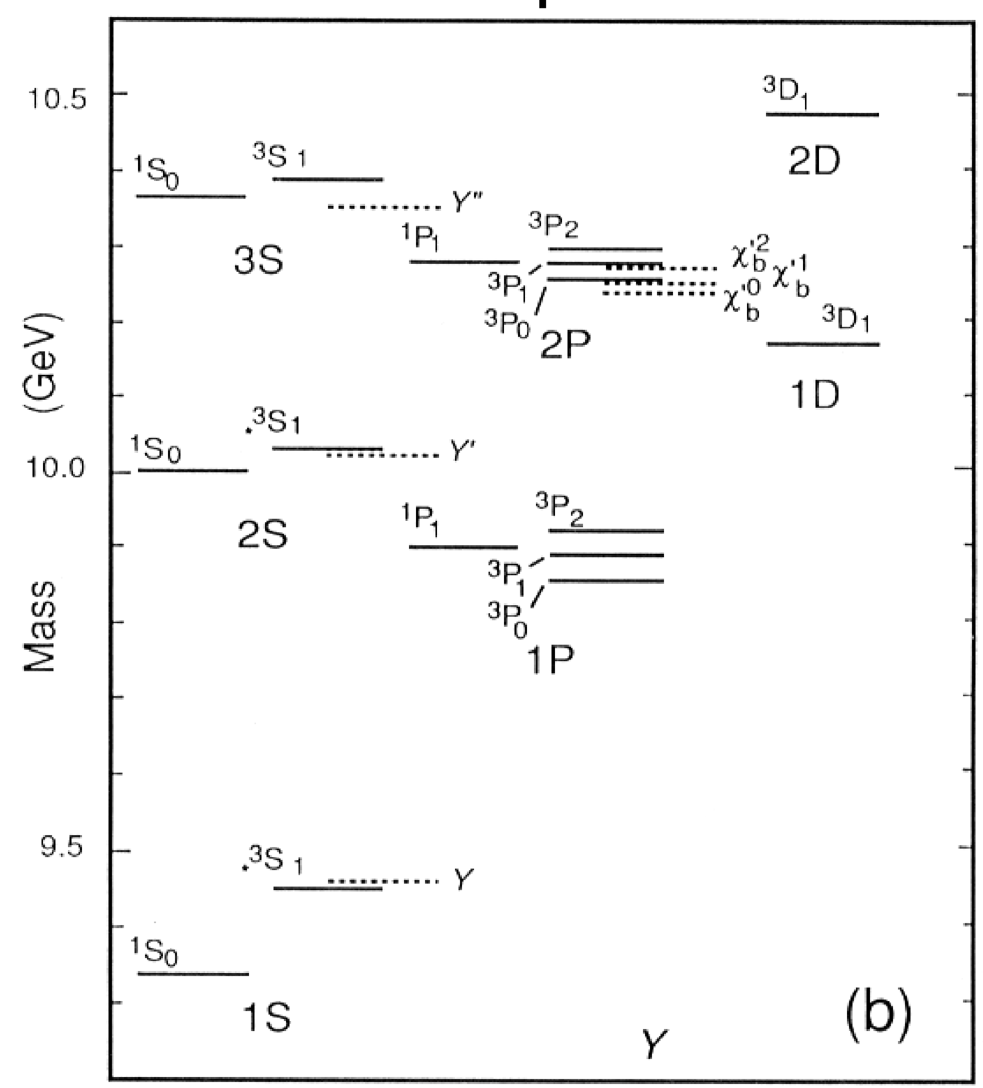
hadronic excited states = excitations of inside quarks

S.N. Mukherjee, et al.
Phys. Rep. 231 (93)

$c^{bar}c$ spectrum



$b^{bar}b$ spectrum



Wednesday, 18 January 2012

Hadron

hadron:

> *a composite particle made of quarks held together by the strong force. ---Wikipedia*

rich spectrum

dynamics of 5 (6) quarks, up, down, strange, charm, bottom, (top)

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experimentally observable objects are hadrons

understanding hadron spectrum is understanding color interaction

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> *Hadrons are categorized into two families: baryons (made of three quarks) and mesons (made of one quark and one antiquark). ---Wikipedia*

baryons are made of three quarks

mesons are made of quark-antiquark pair

quantum numbers of hadrons can be understood by quark model

text-book knowledge of hadron

exotic hadron: hadrons which are not normal hadrons (beyond text-book knowledge)

Multiquark states are exotic

Other types of hadron may exist, such as tetraquarks (or, more generally, exotic mesons) and pentaquarks (exotic baryons), but no current evidence conclusively suggests their existence. ---Wikipedia

text-book knowledge of hadron

baryons are made of three quarks

mesons are made of quark-antiquark pair

multiquark state

ex. the pentaquark ($uudds^{bar}$), strangeness +1

manifestly five quarks (4 q + 1 q^{bar}) necessary

tetraquark states ($qqq^{bar}q^{bar}$)

QCD does not forbid multiquark states, but very few in nature

important to confirm such states really exist in nature or not

Multiquark states are exotic

if exist, we get new samples to study confinement mechanism

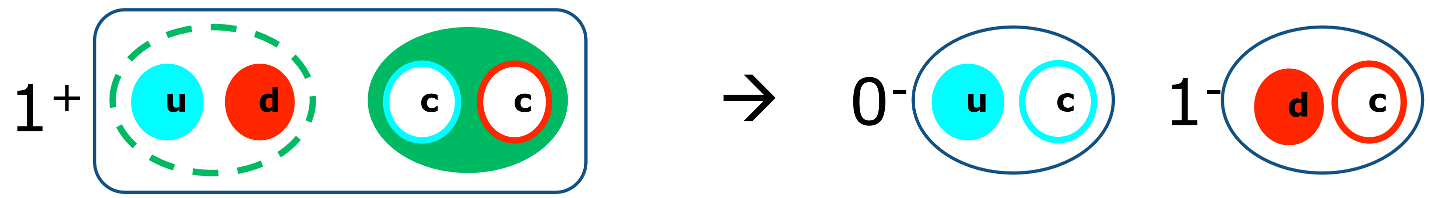
multiquark states have always color-singlet clusters

$$(uudd s^{bar}) \leftrightarrow (uud) + (d s^{bar})$$

colored interaction hadronic (colorless) interaction

multiquark states are formed by
interplay between colored "constituent" force and colorless "interaction" force

ex. $T^{1}_{cc}(ud\bar{c}\bar{c})$ theoretically suggested meson



colored diquarks colorless mesons

if not exist, theory should explain why not.

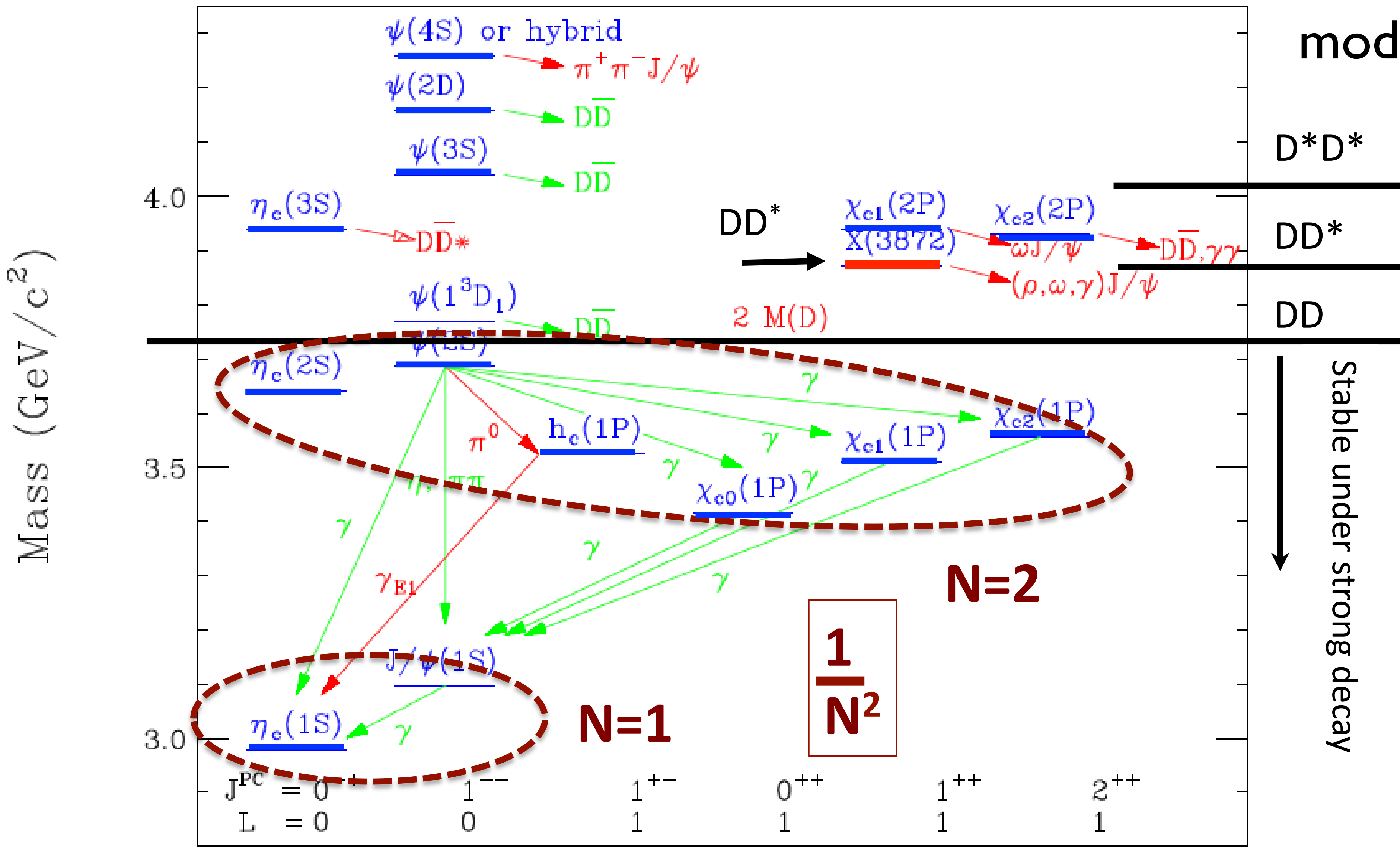
Why is X(3872) exotic ?

charmonium ($c^{bar}c$) spectrum

quark model reproduces spectrum well except X,Y Z states

X(3872) is not a simple c^{bar}-c state

X,Y, Z states have no corresponding quark model levels.



many exotic states are found above thresholds of strong decays

hadron dynamics is also key to understand exotic hadrons

Other examples

see article coming in 学会誌 and
recent review [Prog. Part. Nucl. Phys. 67, 55-98 (2012)]
by T. Hyodo and DJ.

light hadrons which are hard to be explained by simple quark models

scalar mesons

f_0(980), a_0(980)

first excitation of Λ baryon (uds)

Λ(1405)

can be exotic hadrons

Other examples

see article coming in 学会誌 and
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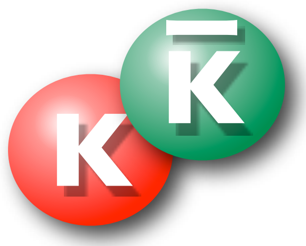
light hadrons which are hard to be explained by simple quark models

scalar mesons

f_0(980), a_0(980)



BE ~10 MeV

first excitation of Λ baryon (uds)

Λ(1405)

BE ~10 MeV (or more)

can be exotic hadrons

strong theoretical suggestions that they are explained by hadronic molecular states

considering these hadrons as building blocks,
we predict more few-body systems with kaons and nucleons

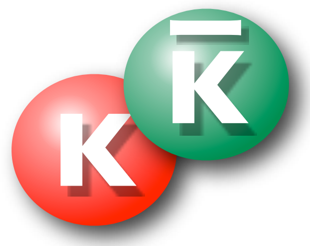
Other examples

see article coming in 学会誌 and
recent review [Prog. Part. Nucl. Phys. 67, 55-98 (2012)]
by T. Hyodo and DJ.

light hadrons which are hard to be explained by simple quark models

scalar mesons

f_0(980), a_0(980)



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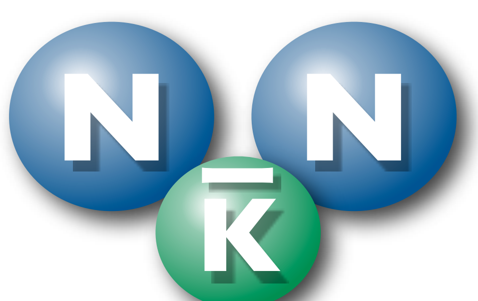
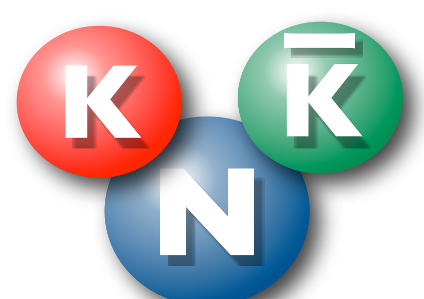
K^{bar}NN



BE ~20 MeV
(or more)

N*
$J^P=1/2^+$

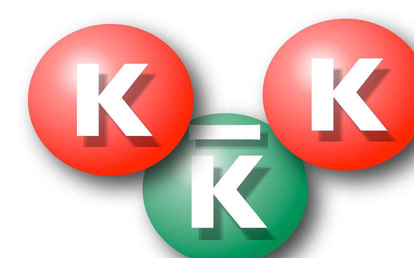
K^{bar}KN



BE ~20 MeV

K*
$J^P=0^-$

K^{bar}KK



BE 20~60 MeV

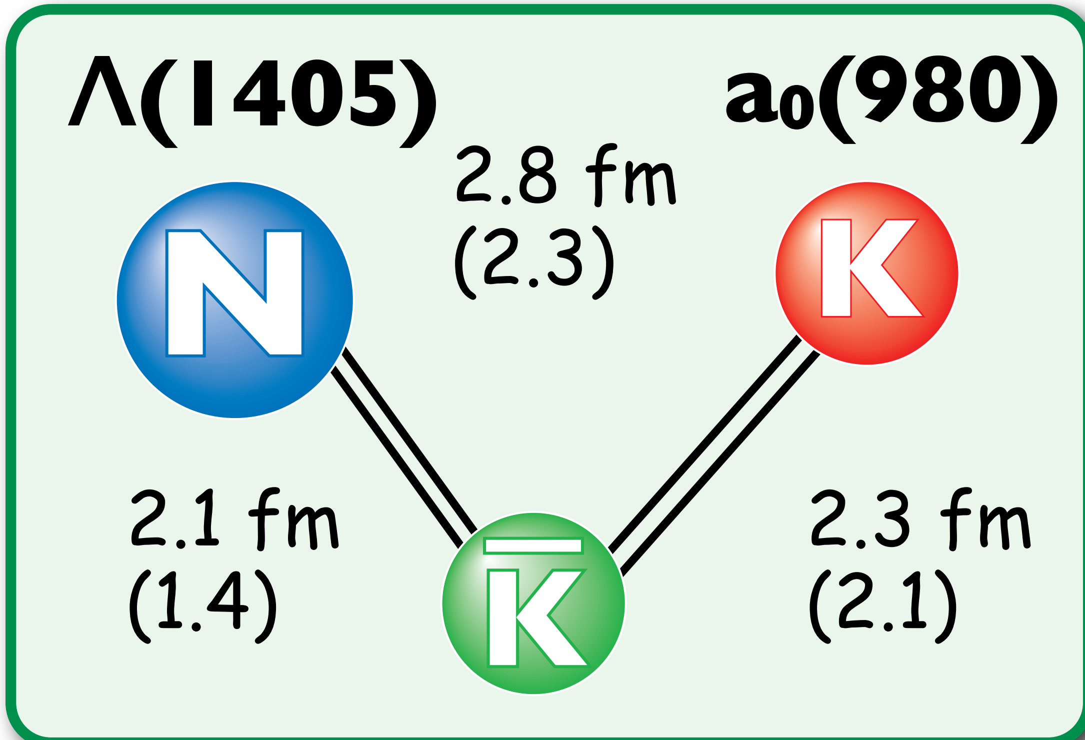
systematics **family of kaonic few-body systems**

Structure of N*(1910)

DJ, Y. Kanada-En'yo, **PRC78, 035203 (2008)**

1) relativistic potential model

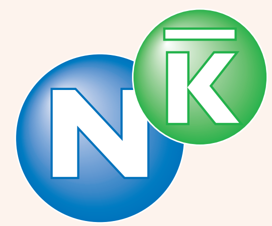
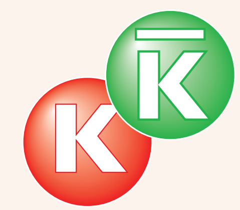
spatial structure



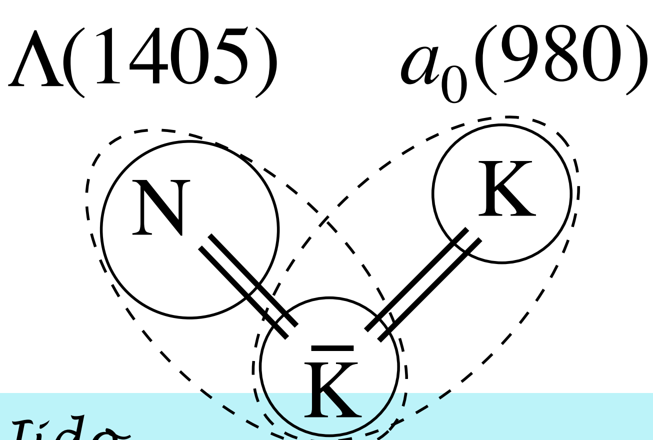
r.m.s radius: **1.7 fm** cf. 1.4 fm for ^{4}He

hadron-hadron distances are comparable with nucleon-nucleon distances in nuclei

mean hadron density: **0.07 hadrons/fm^3**

Λ(1405)	***a_0(980)***
 HW: 1.9 fm AY: 1.4 fm	 HW: 2.1 fm AY: 2.2 fm

- coexistence of two quasi-bound states keeping their characters



Λ(1405)+K

a_0(980)+N

- main decay modes

$\pi\Sigma K$ from Λ(1405)

$\pi\eta N$ from a_0(980)

Summary

Exotic hadron:

hadrons cannot be described by three quarks nor quark-antiquark pair

multiquark states

several quarks are confined in a single confinement potential

dynamical competition between qq and q^{bar}q

can learn confinement mechanism

hadronic molecular states

hadrons are constituents

hadronic (colorless) interaction is diving force

can learn hadronic interaction

and others

hadron spectrum is richer than what we expected

quark excitation in confinement potential is not only the excitation mode

qqbar, hadronic, diquark excitations, etc. are also possible

interplay between quark dynamics and hadron dynamics

detailed investigation makes exotic hadrons be normal