Exotic Hadrons in s-Wave Chiral Dynamics

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2007, Mar. 28th

Exotic hadrons in hadron spectrum

Observed hadrons in experiments (PDG06) :

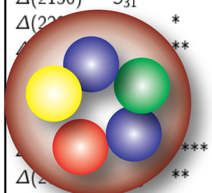
p	P_{11}	****
n	P_{11}	****
$N(1440)$	P_{11}	****
$N(1520)$	D_{13}	****
$N(1535)$	S_{11}	****
$N(1650)$	S_{11}	****
$N(1675)$	D_{15}	****
$N(1680)$	F_{15}	****
$N(1700)$	D_{13}	***
$N(1710)$	P_{11}	***
$N(1720)$	P_{13}	****
$N(1900)$	P_{13}	**
$N(1990)$	F_{17}	**
$N(2000)$	F_{15}	**
$N(2080)$	D_{13}	**
$N(2090)$	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}	*
$\Delta(22$[illegible]	[illegible]	*
[illegible]	[illegible]	**
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	***
$\Delta(2$[illegible]	[illegible]	**
$\Delta(2950)$	$K_{3,15}$	**
$\Theta(1540)^+$		*

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}	***
$\Lambda(2585)$		**

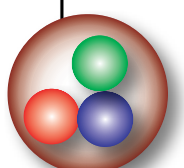
Σ^+	P_{11}	****
Σ^0	P_{11}	****
Σ^-	P_{11}	****
$\Sigma(1385)$	P_{13}	****
$\Sigma(1480)$		*
$\Sigma(1560)$		**
$\Sigma(1580)$	D_{13}	*
$\Sigma(1620)$	S_{11}	**
$\Sigma(1660)$	P_{11}	***
$\Sigma(1670)$	D_{13}	****
$\Sigma(1690)$		**
$\Sigma(1750)$	S_{11}	***
$\Sigma(1770)$	P_{11}	*
$\Sigma(1775)$	D_{15}	****
$\Sigma(1840)$	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^+		****
$\Lambda_c(2593)^+$		***
$\Lambda_c(2625)^+$		***
$\Lambda_c(2765)^+$		*
$\Lambda_c(2880)^+$		**
$\Sigma_c(2455)$		****
$\Sigma_c(2520)$		***
$\Sigma_c(2800)$		***
Ξ_c^+		***
Ξ_c^0		***
$\Xi_c^{\prime +}$		***
$\Xi_c^{\prime 0}$		***
$\Xi_c(2645)$		***
$\Xi_c(2790)$		***
$\Xi_c(2815)$		***
Ω_c^0		***
Ξ_{cc}^+		*
Λ_b^0		***



$\sim \dfrac{1}{300}$!

~130 baryons



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

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

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

CHARMED ($C = \pm1$)

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

[illegible] ($S = \pm1$)

• $D_s^\pm$	$0(0^-)$
• $D_s^{*\pm}$	$0(?^?)$
• $D_{s0}^*(2317)^\pm$	$0(0^+)$
• $D_{s1}(2460)^\pm$	$0(1^+)$
• $D_{s1}(2536)^\pm$	$0(1^+)$

BOTTOM ($B = \pm1$)

	$I^G(J^{PC})$
• $B^\pm$	$1/2(0^-)$
• B^0	$1/2(0^-)$
• $B^\pm/B^0$ ADMIXTURE	
• $B^\pm/B^0/B_s^0/b$-baryon ADMIXTURE	
V_{cb} and V_{ub} CKM Matrix Elements	
• B^*	$1/2(1^-)$
$B_J^*(5732)$	$?(?^?)$

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

• B_s^0	$0(0^-)$
B_s^*	$0(1^-)$
$B_{sJ}^*(5850)$	$?(?^?)$

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

• $B_c^\pm$	$0(0^-)$

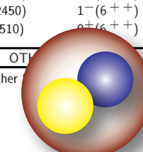
$c\bar{c}$

• $\eta_c(1S)$	$0^+(0^{-+})$
• $J/\psi(1S)$	$0^-(1^{--})$
• $\chi_{c0}(1P)$	$0^+(0^{++})$
• $\chi_{c1}(1P)$	$0^+(1^{++})$
$h_c(1P)$	$?^?(?^{??})$
• $\chi_{c2}(1P)$	$0^+(2^{++})$
• $\eta_c(2S)$	$0^+(0^{-+})$
• $\psi(2S)$	$0^-(1^{--})$
• $\psi(3770)$	$0^-(1^{--})$
• $X(3872)$	$0^?(?^{?+})$
• $\chi_{c2}(2P)$	$0^+(2^{++})$
$Y(3940)$	$?^?(?^{??})$
• $\psi(4040)$	$0^-(1^{--})$
• $\psi(4160)$	$0^-(1^{--})$
$Y(4260)$	$?^?(1^{--})$
• $\psi(4415)$	$0^-(1^{--})$

$b\bar{b}$

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

NON-$q\bar{q}$ CANDIDATES



~160 mesons

Exotic hadrons are indeed exotic !!

Exotic hadrons : experiment vs theory

Exotic hadrons : valence quark-antiquark(s)

non-exotic $uds, \quad u\bar{d}, \quad uds\, u\bar{u}, \quad u\bar{d}\, u\bar{u}, \ldots$

exotic $uudd\bar{s}, \quad ud\bar{s}\bar{s}, \ldots$

Experimentally, they are exotic ~ 1/300.

Theoretically, are they exotic?

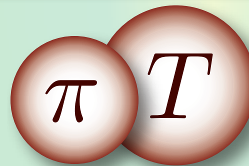
--> There is no simple way to forbid exotic states in QCD, effective models, ...

--> Importance of multiquark components in non-exotic hadrons.

Why aren't the exotics observed??

Non-exotic hadrons in s-wave chiral dynamics

Hadron excited states ~



- Interaction <-- chiral symmetry
- Amplitude <-- unitarity

light baryon	$J^P = 1/2^-$	$\Lambda(1405)$	$\Lambda(1670)$	$\Sigma(1670)$	
		$N(1535)$	$\Xi(1620)$	$\Xi(1690)$	
	$J^P = 3/2^-$	$\Lambda(1520)$	$\Xi(1820)$	$\Sigma(1670)$	
heavy		$\Lambda_c(2880)$	$\Lambda_c(2593)$		$D_s(2317)$
light meson	$J^P = 1^+$	$b_1(1235)$	$h_1(1170)$	$h_1(1380)$	$a_1(1260)$
		$f_1(1285)$	$K_1(1270)$	$K_1(1440)$	
	$J^P = 0^+$	$\sigma(600)$	$\kappa(900)$	$f_0(980)$	$a_0(980)$

What about exotic hadrons?

Exotic hadrons in s-wave chiral dynamics

Hadron-NG boson bound state

π T

Chiral Symmetry

s-wave low energy interaction

$$V_\alpha = -\frac{\omega}{2f^2} C_{\alpha,T} \qquad C_{\text{exotic}} = 1$$

Scattering theory

Critical strength for a bound state

$$C_{\text{crit}} = \frac{2f^2}{m[-G(M_T + m)]}$$

physical values : $C_{\text{exotic}} < C_{\text{crit}}$

→ **No exotic state exists in SU(3) limit.**

T. Hyodo, D. Jido, A. Hosaka, Phys. Rev. Lett. 97, 192002 (2006)

T. Hyodo, D. Jido, A. Hosaka, Phys. Rev. D 75, 034002 (2007)

Topics

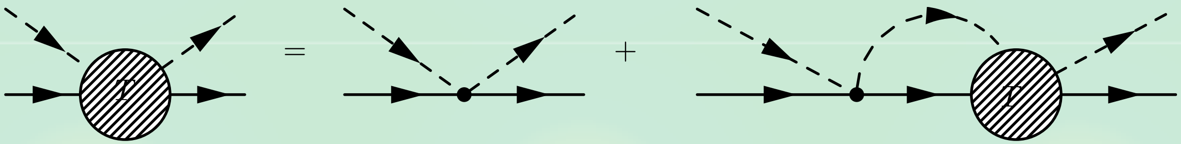
- **Physical meaning of the renormalization condition.**

- **Nc dependence of the interaction and bound states in large Nc limit**

Renormalization condition

Scattering amplitude

$$T = \frac{1}{1 - VG} V$$



$$V_\alpha = -\frac{\omega}{2f^2} C_{\alpha,T}$$ **tree**

$$G(\sqrt{s}) = \frac{2M_T}{(4\pi)^2}\left(a(\mu) + \ln \frac{M_T^2}{\mu^2} + \dots \right)$$ **loop**

Subtraction constant $a(\mu)$: condition

$$G(\mu) = 0, \quad \Leftrightarrow \quad T(\mu) = V(\mu) \quad \text{at} \quad \mu = M_T$$

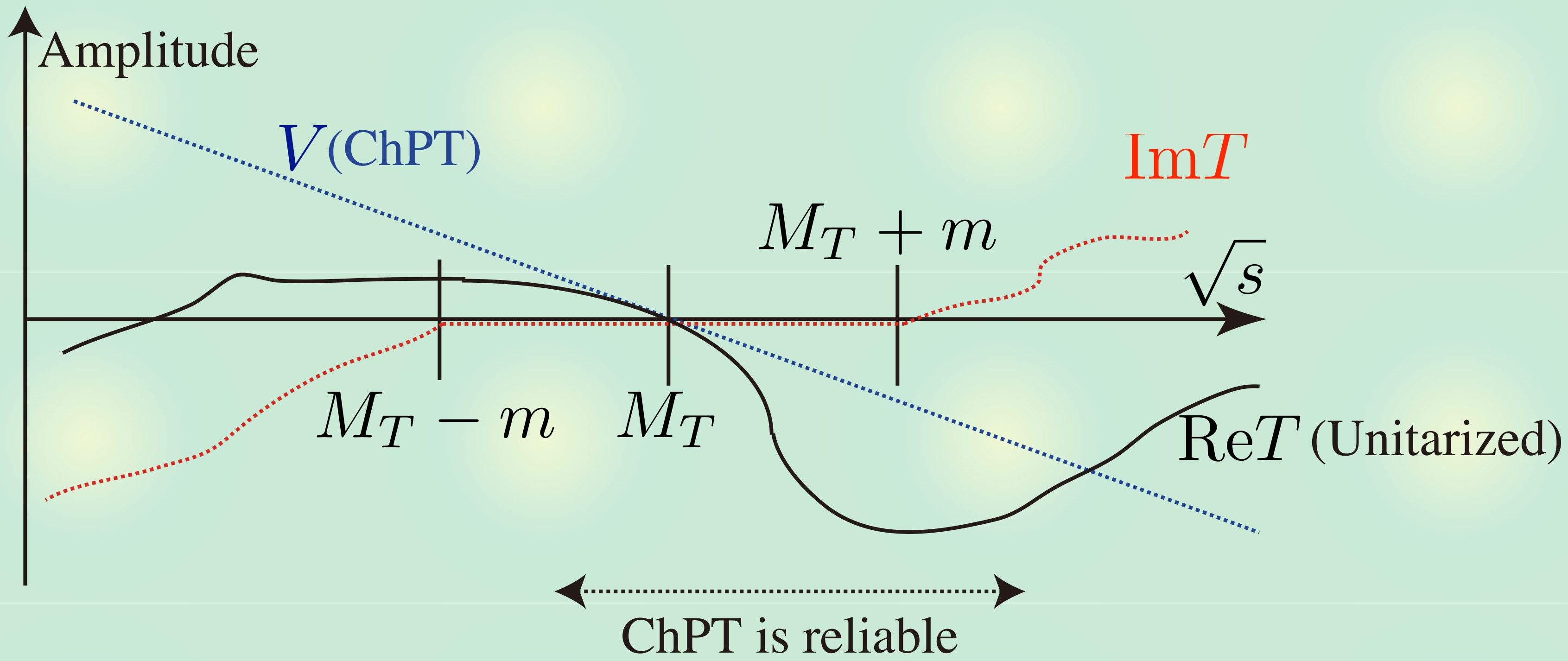
K. Igi, and K. Hikasa, Phys. Rev. D59, 034005 (1999)
M.F.M. Lutz, and E. Kolomeitsev, Nucl. Phys. A700, 193-308 (2002)

Physical meaning of the condition?

Matching with ChPT

Match the unitarized amplitude with ChPT

$$G(\mu_m) = 0, \quad \Leftrightarrow \quad T(\mu_m) = V(\mu_m)$$



subtraction constant : real

$$\Rightarrow \quad M_T - m \leq \mu_m \leq M_T + m$$

Natural value for the subtraction constant

Single-channel case

$$G(\mu_m) = 0, \quad \Leftrightarrow \quad T(\mu_m) = V(\mu_m)$$

$$M_T - m \leq \mu_m \leq M_T + m$$

Coupled-channel case

$$G_i(\mu_m) = 0, \quad \Leftrightarrow \quad T_{ij}(\mu_m) = V_{ij}(\mu_m)$$

$$\mathrm{Max}(M_T - m)_i \leq \mu_m \leq \mathrm{Min}(M_T + m)_i$$

Natural value for the subtraction constant
: consistent with the 3d cutoff ~ 630 MeV

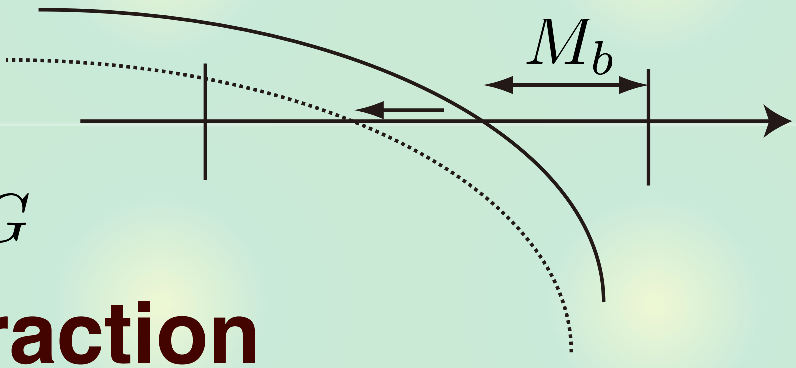
$$a(630\mathrm{MeV}) \sim -2$$

J.A. Oller, U.G. Meissner, Phys. Lett. B500, 263 (2001)

In practice : fitted to the data
Unnatural value -> seed of resonance?

Effective attraction from the loop

Bound state energy M_b :



$$1 - V(M_b)G(M_b) = 0$$

To enlarge M_b : increase VG

$V < 0$ **for attractive interaction**

$$G(\sqrt{s}) = \frac{2M_T}{(4\pi)^2}\left(a(\mu) + \ln\frac{M_T^2}{\mu^2} + \dots\right)$$

larger $(-a)$: smaller μ_m : larger M_b
--> effective attraction

T. Hyodo, S.I. Nam, D. Jido, A. Hosaka, Phys. Rev. C. 68, 018201 (2003)
T. Hyodo, S.I. Nam, D. Jido, A. Hosaka, Prog. Thor. Phys. 112, 73 (2004)

The condition $\mu_m = M_T$: largest effective attraction in s-channel scattering region

Large Nc limit : introduction

1/Nc : a possible expansion parameter

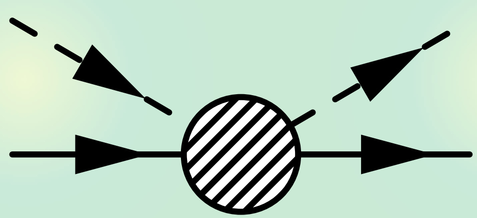
G. ‘t Hooft, Nucl. Phys. B72, 461 (1974)
E. Witten, Nucl. Phys. B160, 57 (1979)

Scaling of the physical quantities <- Nc^2 gluons and Nc quarks.

Meson mass : $m \sim \mathcal{O}(1)$

Baryon mass : $M \sim \mathcal{O}(N_c)$

Decay constant : $f \sim \mathcal{O}(\sqrt{N_c})$

MB scattering :  $\sim \mathcal{O}(1)$

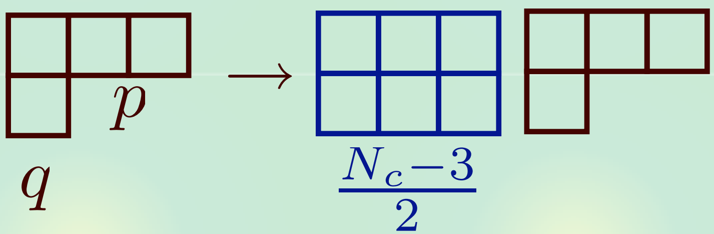
Coupling strengths in large Nc limit

WT interaction in large Nc limit

$$V_\alpha = -\frac{\omega}{2f^2} C_{\alpha,T} \sim \frac{1}{N_c} \times C_{\alpha,T}$$

Flavor representation of baryons

$$[p,q] \to \text{“}[p,q]\text{”} = [p, q + \tfrac{N_c - 3}{2}]$$



Coupling strength has linear Nc dependence

$$\underline{C_{\text{“}\alpha\text{”},\text{“}T\text{”}}(N_c)} = C_2(\text{“}T\text{”}) - C_2(\text{“}\alpha\text{”}) + 3$$

$$C\,(\text{“}[p,q]\text{”}) = \frac{1}{3}\left(-\frac{9}{4} + p^2 + \frac{3p}{2} + pq + q^2\right) + \underline{\frac{1}{3}\left(\frac{p}{2} + q\right) N_c} + \frac{N_c^2}{12}$$

Coupling strengths for the general target

For arbitrary Nc, $V \propto -\frac{C}{f^2} \sim -\frac{C(N_c)}{N_c}$

$\alpha \in [p,q] \otimes [1,1]$	$C_{\text{``}\alpha\text{''},\text{``}T\text{''}}(N_c)$	$V(N_c \to \infty)$
$[p+1, q+1]$	$(3-N_c)/2 - p - q$	repulsive
$[p+2, q-1]$	$1-p$	
$[p-1, q+2]$	$(5-N_c)/2 - q$	repulsive
$[p, q]$	3	
$[p, q]$	3	
$[p+1, q-2]$	$(3+N_c)/2 + q$	attractive
$[p-2, q+1]$	$3+p$	
$[p-1, q-1]$	$(5+N_c)/2 + p + q$	attractive

- **No attraction in exotic channels.**

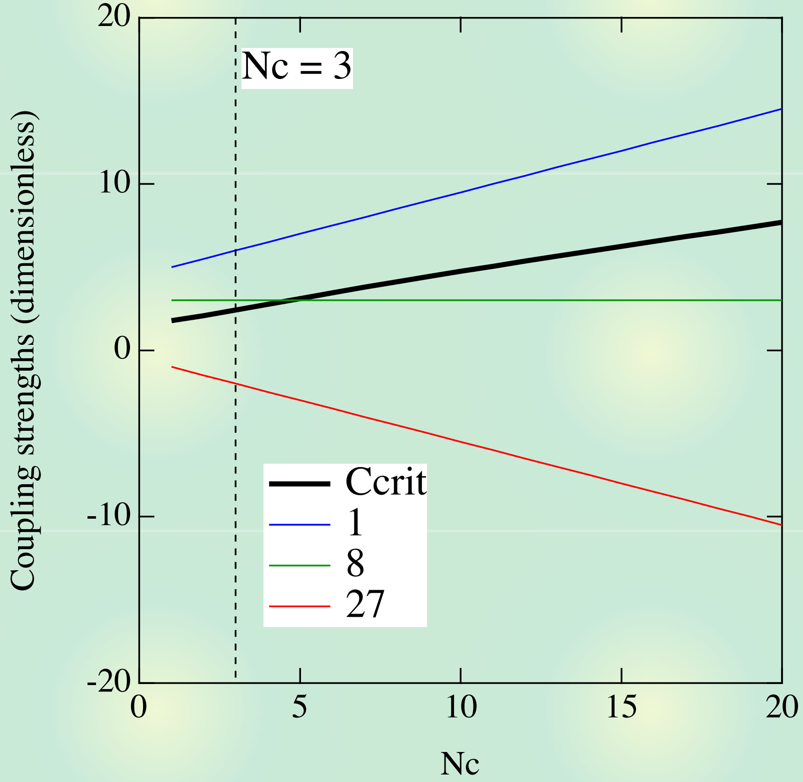
S = -1 I = 0 channel in SU(3) basis

α	"1"	"8_s"	"8_a"	"27"
$T =$ "8"	$\frac{9+N_c}{2}$	3	3	$\frac{-2-N_c}{2}$

$$C_{\mathrm{crit}}(N_c) = \frac{2[f(N_c)]^2}{m[-G(M_T(N_c)+m)]}$$

$$M_T(N_c) = M_0 \times \frac{N_c}{3}$$

$$f(N_c) = f_0 \times \sqrt{\frac{N_c}{3}}$$



○ **Bound state in "1" in the large Nc limit.**

S = -1 I = 0 channel in Isospin basis

Basis transformation via CG Coef. with Nc

T.D. Cohen, and R.F. Lebed, Phys. Rev. D 70, 096015 (2004)

$$
\begin{array}{cccc} \bar{K}N & \pi\Sigma & \eta\Lambda & K\Xi \end{array}
$$

$$
C_{ij}(N_c) = \begin{pmatrix} \frac{1}{2}(3+N_c) & -\frac{\sqrt{3}}{2}\sqrt{-1+N_c} & \frac{\sqrt{3}}{2}\sqrt{3+N_c} & 0 \\ -\frac{\sqrt{3}}{2}\sqrt{-1+N_c} & 4 & 0 & \frac{\sqrt{3+N_c}}{2} \\ \frac{\sqrt{3}}{2}\sqrt{3+N_c} & 0 & 0 & -\frac{\sqrt{3}}{2}\sqrt{-1+N_c} \\ 0 & \frac{\sqrt{3+N_c}}{2} & -\frac{\sqrt{3}}{2}\sqrt{-1+N_c} & \frac{1}{2}(9-N_c) \end{pmatrix}
$$

Combining with the 1/Nc factor of $1/f^2$,

- $\bar{K}N \to \bar{K}N$: **attractive** at large Nc
- $\bar{K}N \to \pi\Sigma$: $\mathcal{O}(1/\sqrt{N_c})$
- $\pi\Sigma \to \pi\Sigma$: $\mathcal{O}(1/N_c)$

Summary 1 : Exotic hadrons

We study the exotic bound states in s-wave chiral dynamics in flavor SU(3) limit.

- **The interaction in exotic channels is in most cases repulsive.**
- **There are attractive interactions in exotic channels, with universal and the smallest strength :** $C_{\text{exotic}} = 1$
- **The strength is not enough to generate a bound state :** $C_{\text{exotic}} < C_{\text{crit}}$

The result is model independent as far as we respect chiral symmetry.

Summary 2 : Topics

- **Physical meaning of the renormalization condition.**

  The renomlization condition provides the largest strength of the effective attraction in the s-channel region.

- **Nc dependence of the interaction and bound states in large Nc limit**

  Attraction in "1" and $\bar{K}N$ channels is strong enough to provide a bound state in the large Nc limit.