Heavy baryons in a pion mean-field approach

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Baryons in large Nc

- **Witten's seminal idea: Baryon in the large Nc**

NPB, 149(1979)285

-Problem in low-energy QCD: Large value of the strong coupling constant

The number of color as an implicit expansion parameter

→ * A baryon can be viewed as a state of Nc quarks bound by mesonic **mean fields**.

Its mass is proportional to Nc, while its width is of order O(1).

→ Mesons are weakly interacting

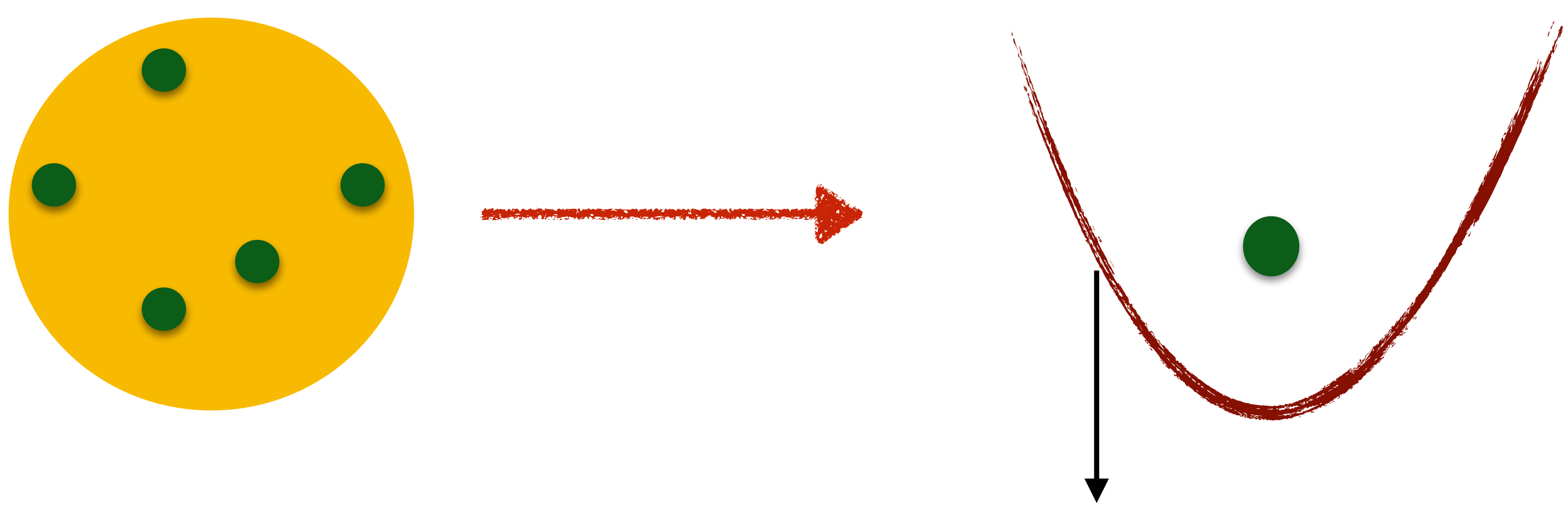
(Quantum fluctuations are suppressed by 1/Nc: O(1/Nc)).

Mean fields

Given action $S[\phi]$,

$$\left.\frac{\delta S}{\delta \phi}\right|_{\phi=\phi_0} = 0$$: Solution of this saddle-point equation ϕ_0

This classical solution is regarded as a mean field.



Mean-field potential that is produced by all other particles.

- Nuclear shell models
- Ginzburg-Landau theory for superconductivity
- Quark potential models for baryons

Pion mean-field approach (Chiral Quark-Soliton model)

✱ Baryons as a state of Nc quarks bound by mesonic mean fields.

Effective chiral action:

$$S_{\rm eff}[\pi^a] = -N_c {\rm Trlog}\left(i\partial\!\!\!/ + iMU^{\gamma_5} + i\hat{m}\right)$$

✱ Key point: Hedgehog Ansatz

$$\pi^a(\boldsymbol{r}) = \begin{cases} n^a F(r),\ n^a = x^a/r, & a = 1,\,2,\,3 \\ 0, & a = 4,\,5,\,6,\,7,\,8. \end{cases}$$

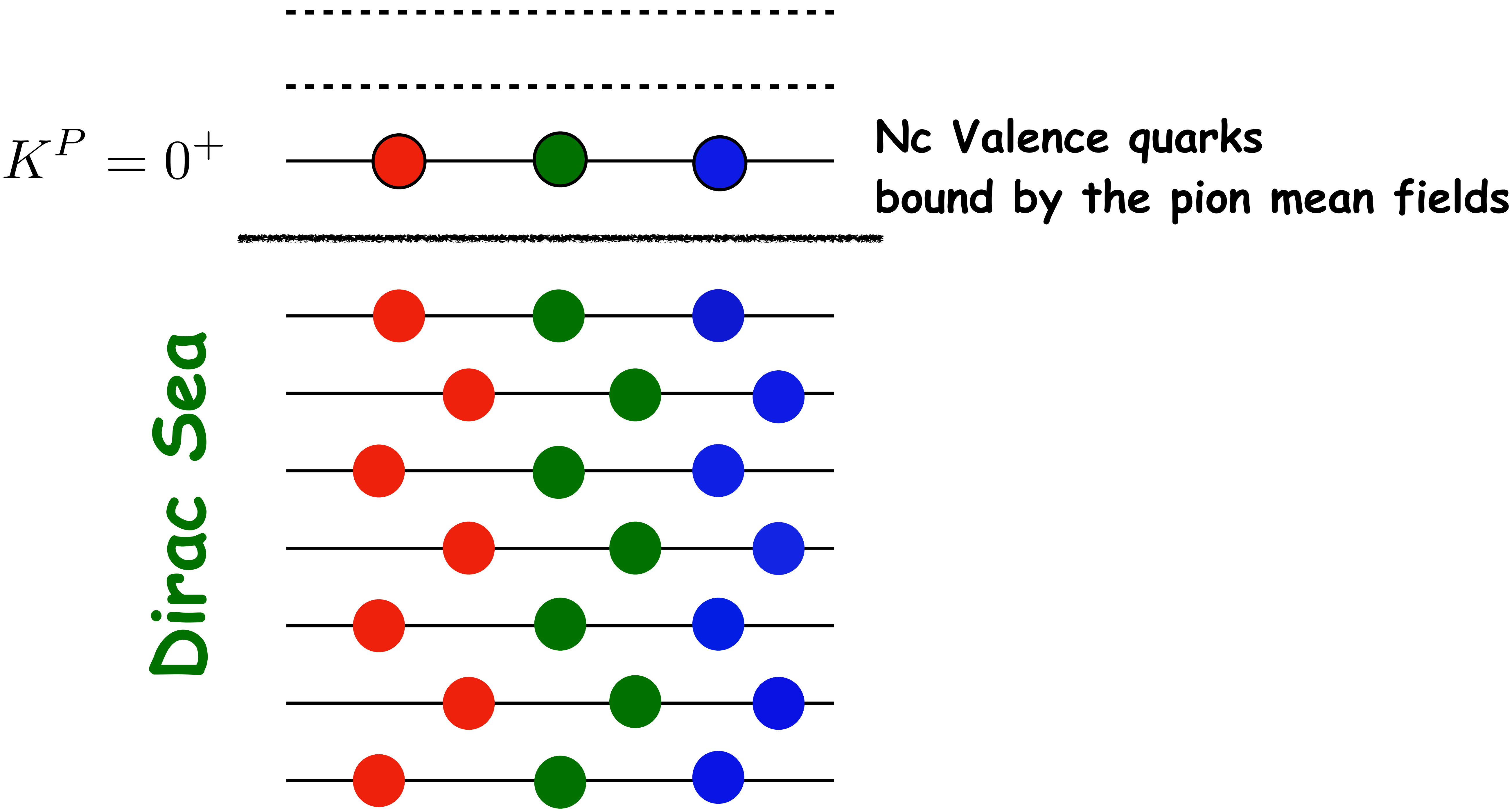
It breaks spontaneously $\mathrm{SU(3)_{flavor}} \otimes \mathrm{O(3)_{space}} \to \mathrm{SU(2)_{isospin+space}}$

Witten's trivial embedding $$U_o = \begin{pmatrix} e^{i\boldsymbol{n}\cdot\boldsymbol{\tau}P(r)} & 0 \\ 0 & 1 \end{pmatrix}$$

Diakonov et al., NPB, 306 (1988) 809

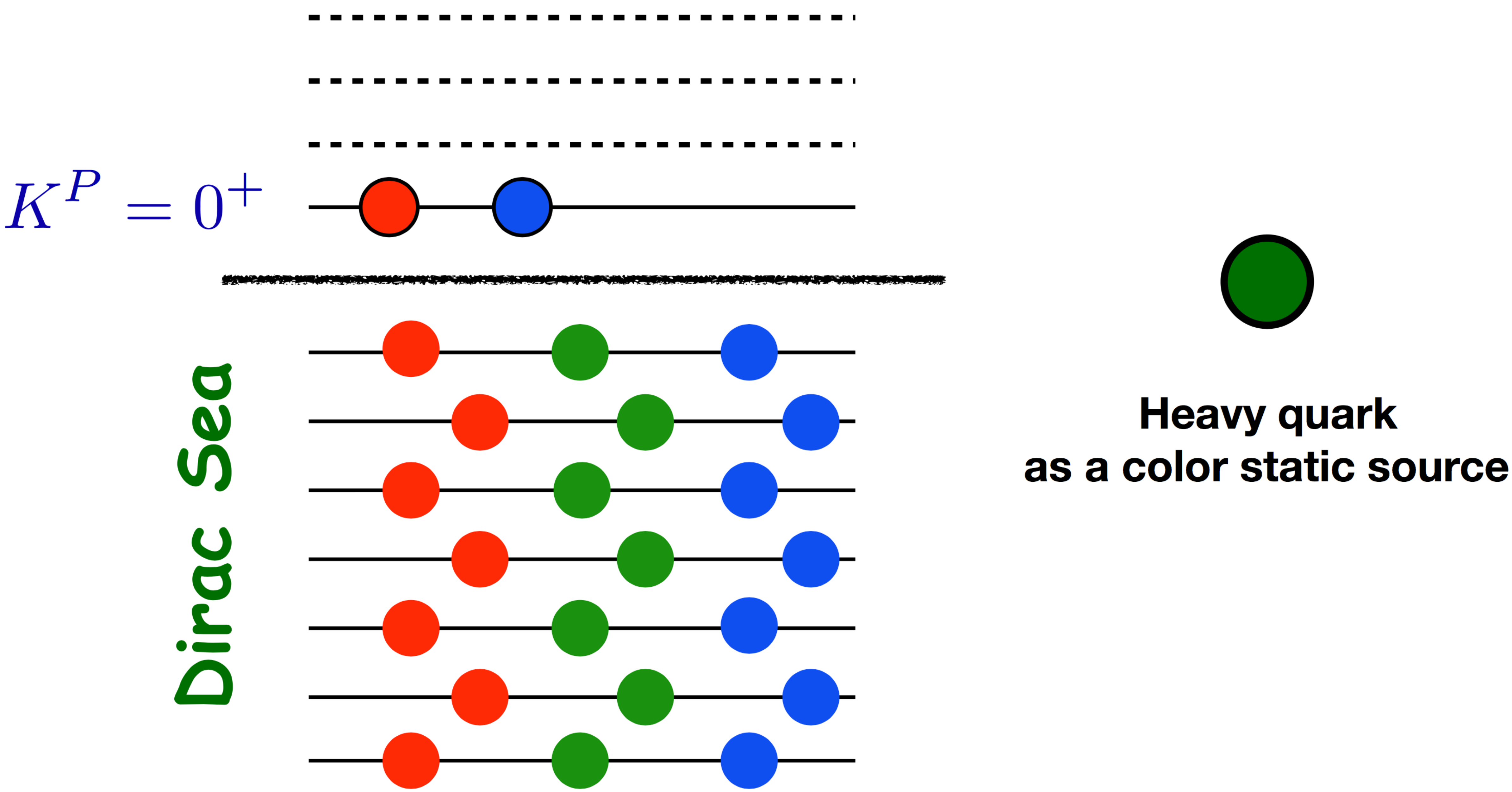
Ch. Christov, H.-Ch.K et al. PPNP, 37 (1996) 91

Light baryons in the XQSM



Light Baryon: Nc light quarks bound by the pion mean fields.

Heavy baryons in the XQSM



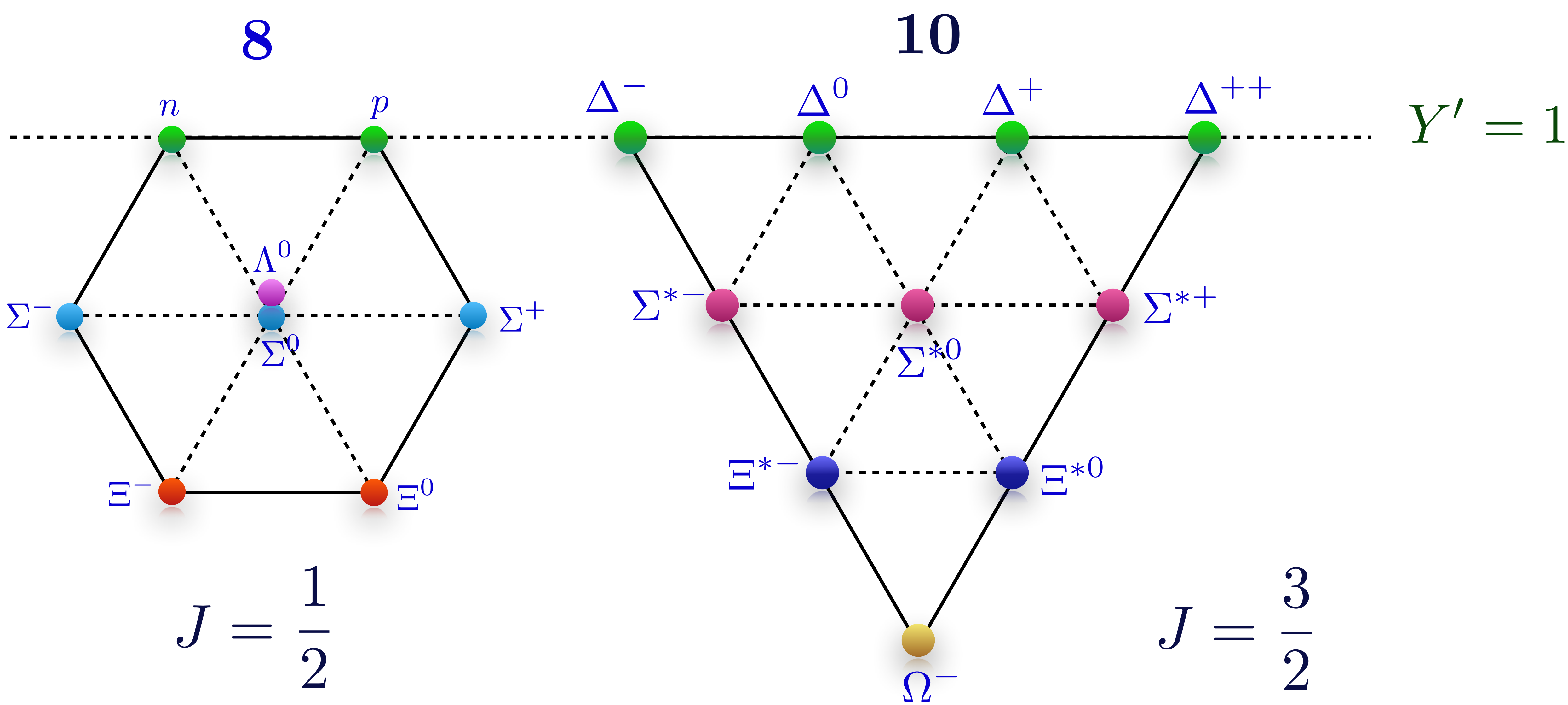
Heavy Baryon: Nc-1 light quarks govern a singly heavy baryon.

Light baryons in the XQSM

A light baryon: Nc quarks bound by the pion mean fields.

$Y' = \frac{N_c}{3}$ Grand spin: $K = 0 \rightarrow T = J$

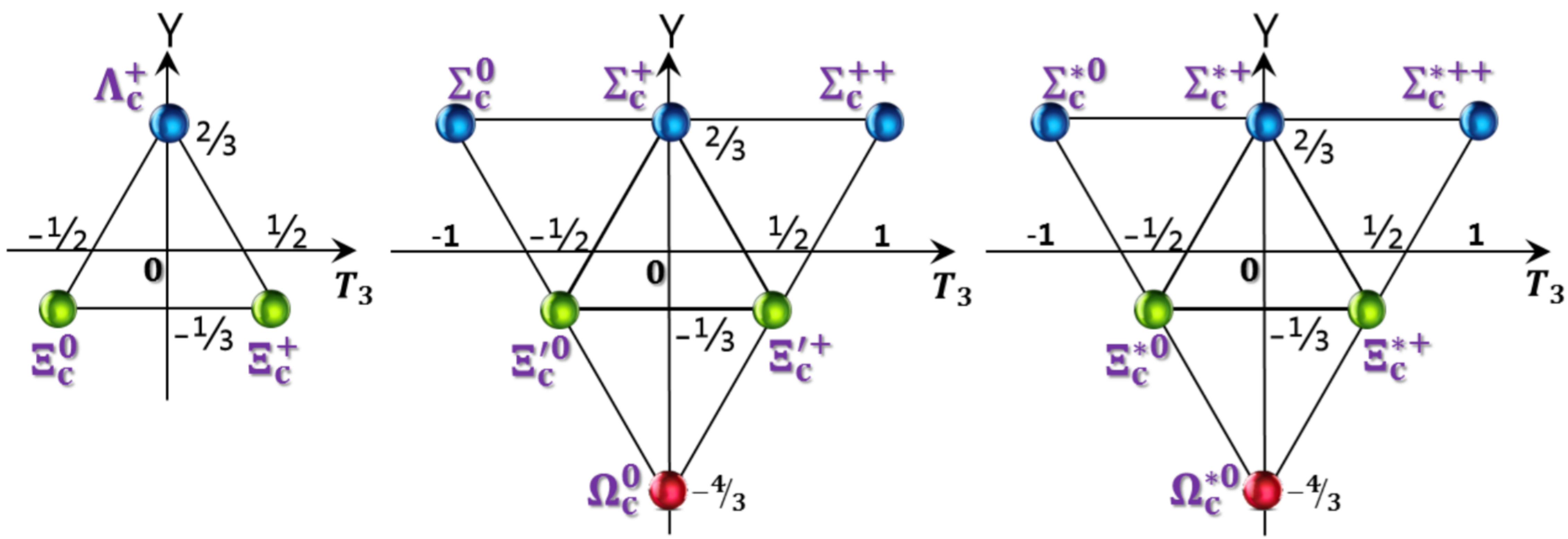
- The lowest rotationally excited states:



Singly heavy baryons in SU(3)

- In the heavy quark mass limit, a heavy quark spin is conserved, so light-quark spin is also conserved.
- In this limit, heavy baryons are independent of heavy-quark flavors.
- In this limit, a heavy quark can be considered as **a static color source**.
- Dynamics is governed by light quarks.

$$\mathbf{3}\otimes\mathbf{3}=\overline{\mathbf{3}}\oplus\mathbf{6}$$



$[\overline{3}]=D(0,1)$, $J=1/2$

$[6]=D(2,0)$, $J=1/2$

$[6]=D(2,0)$, $J=3/2$

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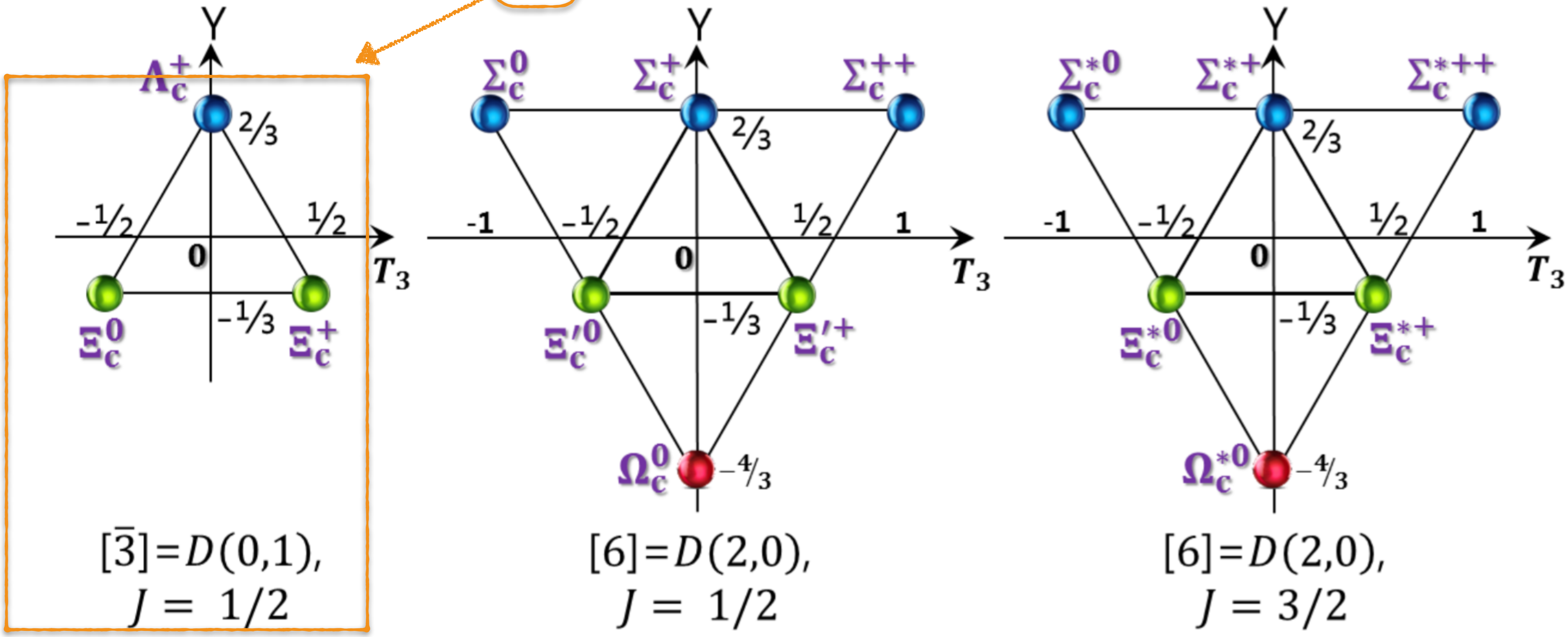

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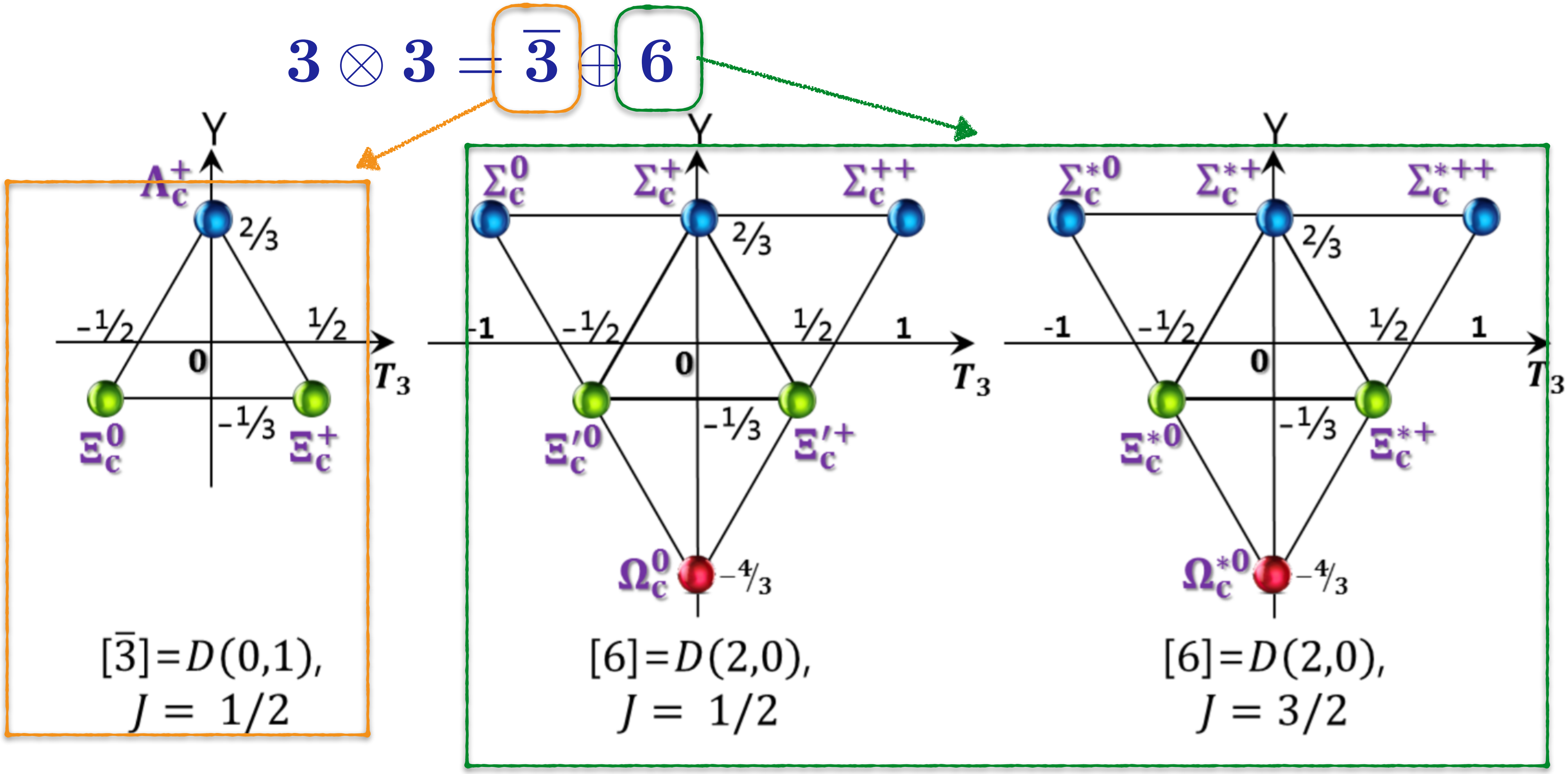


Heavy baryons in the XQSM

Nc-1 quarks represent heavy-baryon spectra.

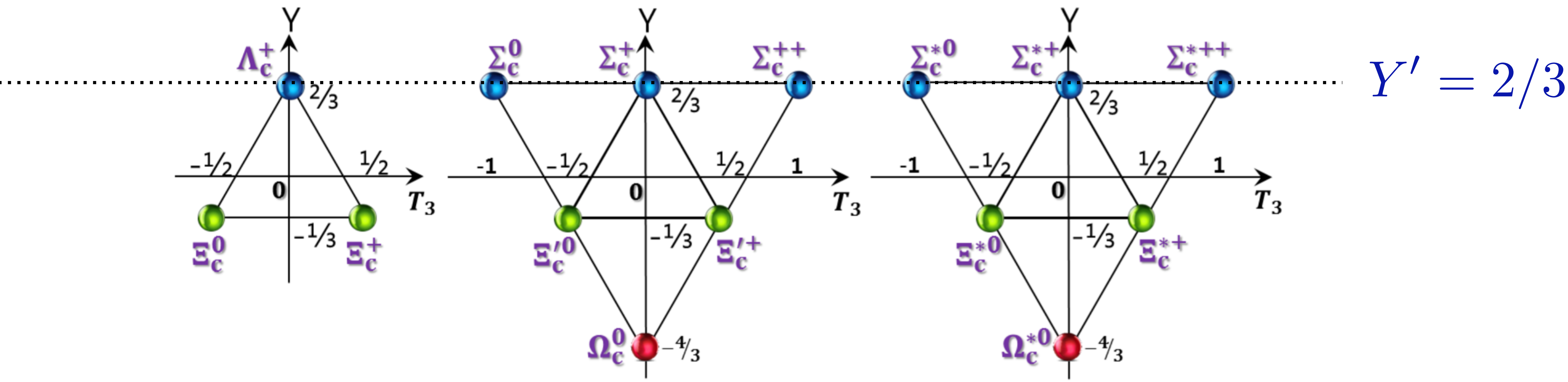
$$Y' = \frac{N_c - 1}{3}$$

Grand spin: $K = 0 \rightarrow T = J$

- The lowest rotationally excited states $\mathbf{3} \times \mathbf{3} = \overline{\mathbf{3}} + \mathbf{6}$

✱ T=0 for a anti-triplet: J=0 for it. Combining a charm quark with spin 1/2, we have one anti-triplet.

✱ T=1 for a sextet: J=1. We have two sextets with a charm quark. (1/2, 3/2).



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Modified Collective Hamiltonian

Modifying Collective rotational Hamiltonian

$$H^{\mathrm{rot}}_{(p,q)} = M_{\mathrm{sol}} + \frac{1}{2I_1}\sum_{i=1}^{3}\hat{J}_i^2 + \frac{1}{2I_2}\sum_{a=4}^{7}\hat{J}_a^2$$

$$\mathcal{E}^{\mathrm{rot}}_{(p,\,q)} = M_{\mathrm{sol}} + \frac{J(J+1)}{2I_1} + \frac{C_2(p,q) - J(J+1) - 3/4\,Y'^{\,2}}{2I_2}$$

G. S. Yang, HChK, PTP, 128, 397 (2012).

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Nc-1 soliton mass (B=2/3)

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Moments of Inertia and Sigma pi-N term: sum over valence quark states:

$$I_{1,\,2},\quad K_{1,\,2},\quad \Sigma_{\pi N} \longrightarrow \left(\frac{N_c-1}{N_c}\right)I_{1,\,2},\quad \left(\frac{N_c-1}{N_c}\right)K_{1,\,2},\quad \left(\frac{N_c-1}{N_c}\right)\Sigma_{\pi N},$$

G. S. Yang, HChK, PTP, 128, 397 (2012).

SU(3) symmetry breaking

- The collective Hamiltonian for SU(3) symmetry breaking

$$H_{\rm br} = \alpha D^{(8)}_{88} + \beta Y + \frac{\gamma}{\sqrt{3}} \sum_{i=1}^{3} D^{(8)}_{8i} J_i$$

In the light-quark sector, we have fixed already these dynamical parameters as

$$\alpha = -\frac{2m_s}{3}\sigma - \beta Y' = -(255.03 \pm 5.82)\,\mathrm{MeV}$$

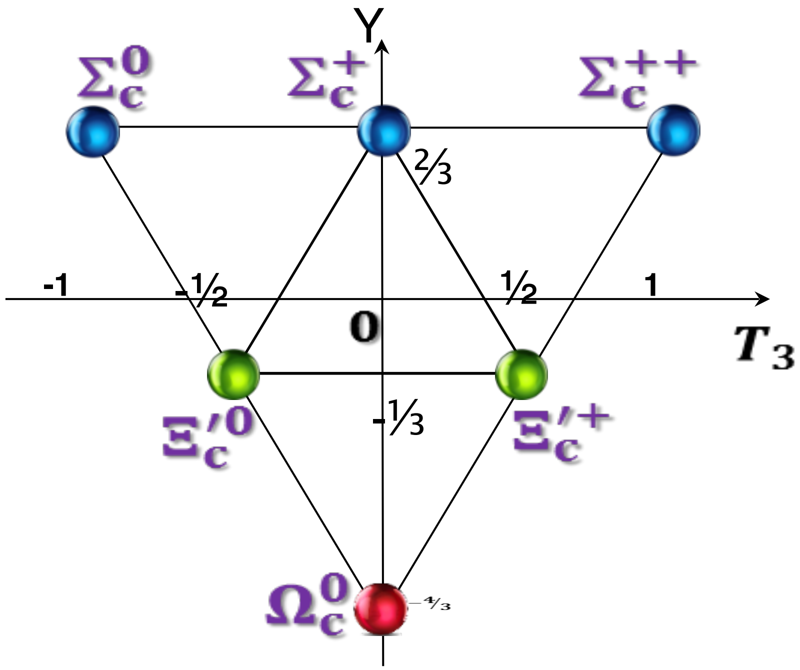
$$\beta = -\frac{m_s K_2}{I_2} = -(140.04 \pm 3.20)\,\mathrm{MeV}$$

$$\gamma = \frac{2m_s K_1}{I_1} + 2\beta = -(101.08 \pm 2.33)\,\mathrm{MeV}$$

For the singly heavy baryons: $\alpha \to \bar{\alpha} = \dfrac{N_c - 1}{N_c}\alpha$

G. S. Yang, HChK, PTP, 128, 397 (2012).

Hyperfine mass splittings (only new parameter)



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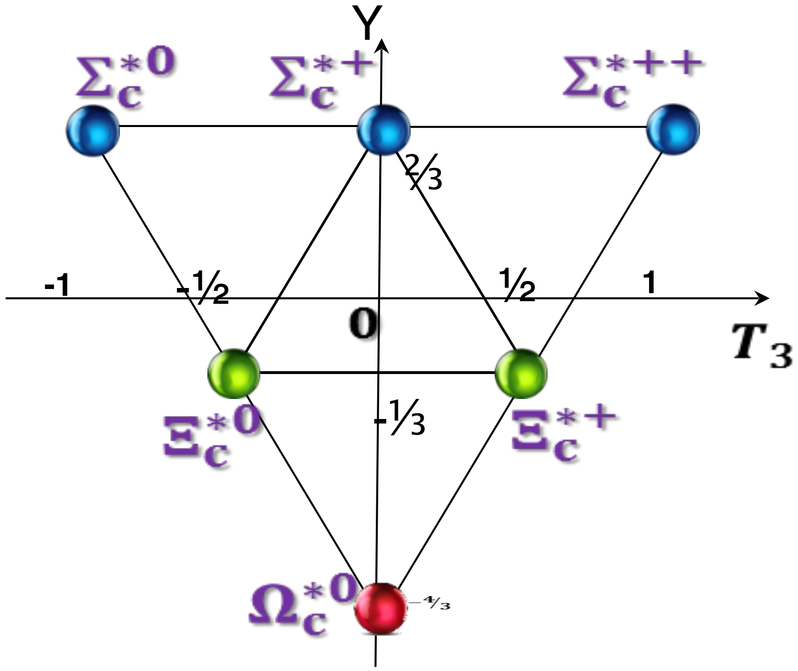

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Gh.S. Yang, HChK, M. Polyakov, M. Praszalowicz, PRD **94**, 071501(R) (2016)

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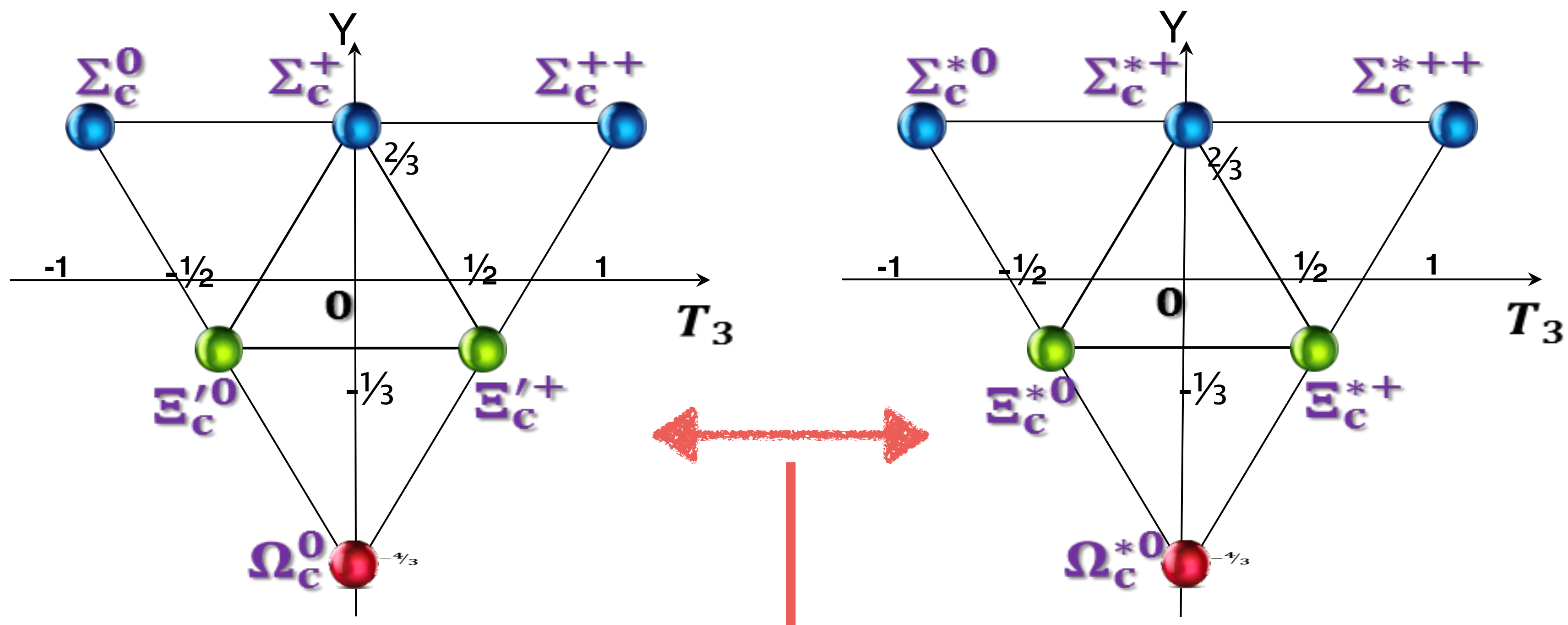

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Hyperfine splitting between different spin states

$$H_{LQ} = \frac{2}{3}\frac{\kappa}{m_Q\, M_{\rm sol}}\mathbf{S}_{\rm L}\cdot\mathbf{S}_Q = \frac{2}{3}\frac{\varkappa}{m_Q}\mathbf{S}_{\rm L}\cdot\mathbf{S}_Q$$

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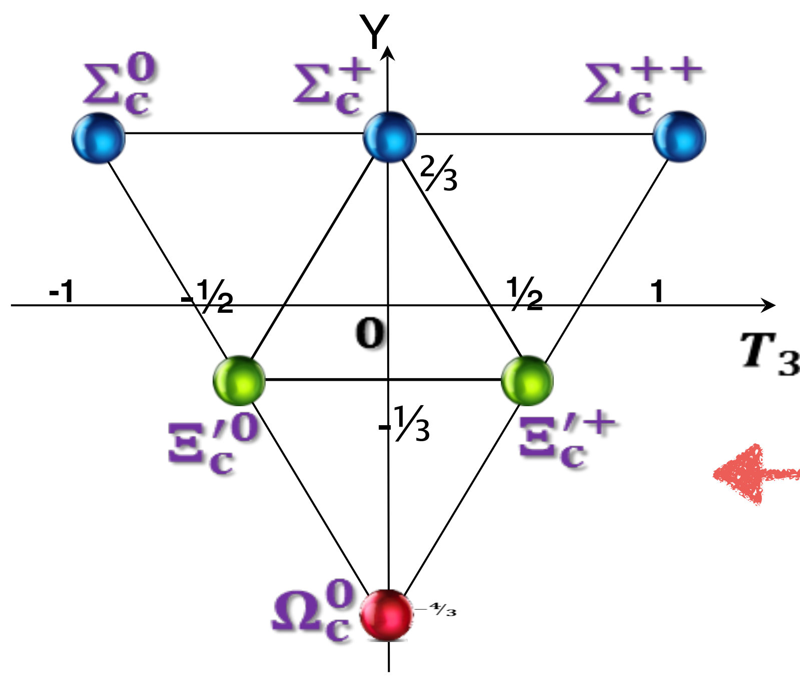

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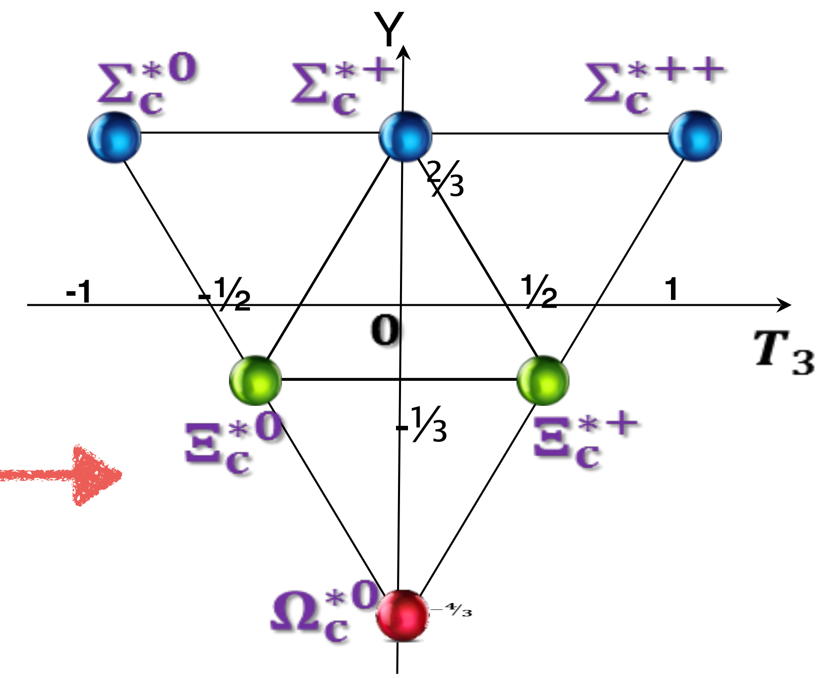

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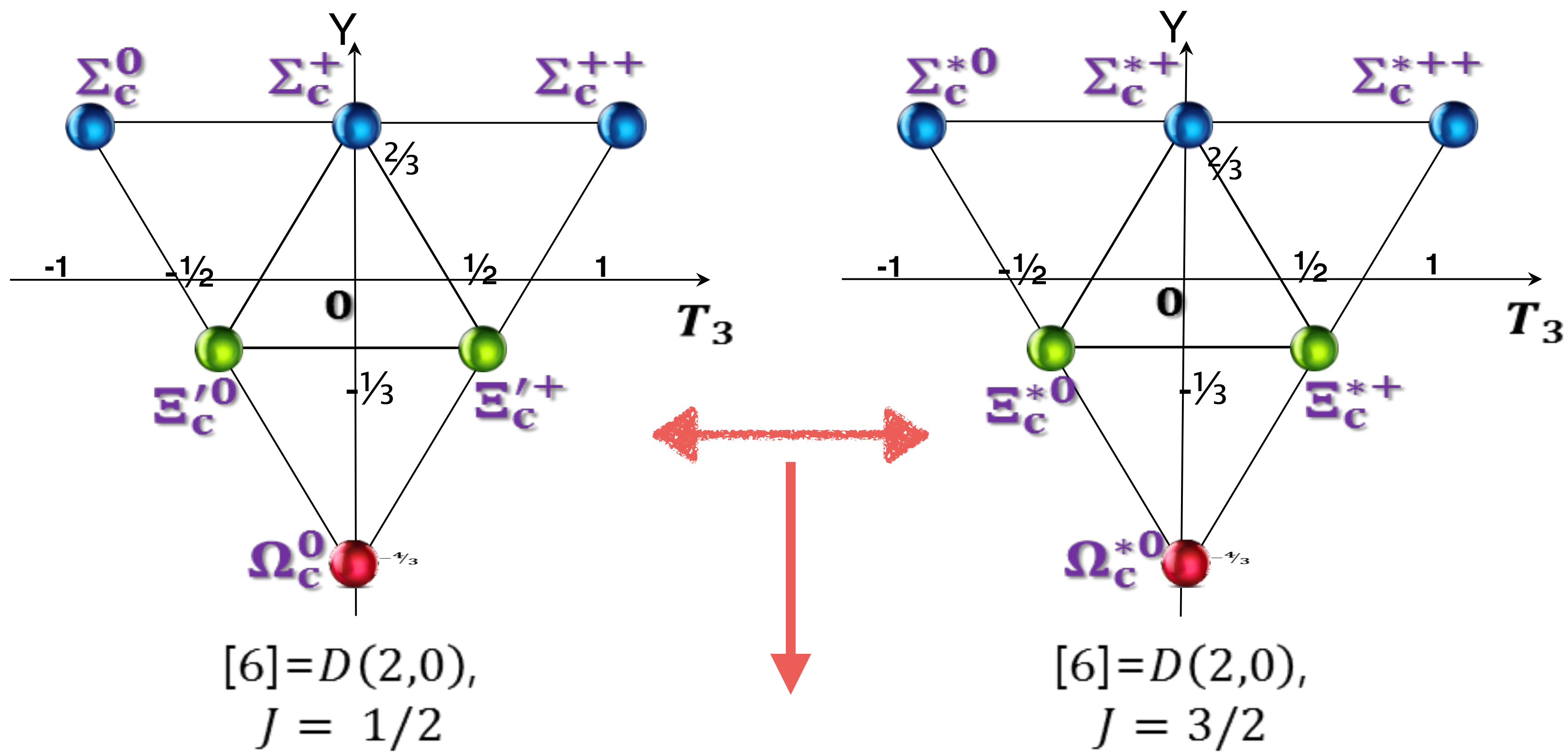

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The ratio can be determined by the center values of the sextet masses

$$\frac{\varkappa}{m_c} = (68.1 \pm 1.1)\,\mathrm{MeV}$$

$$\frac{\varkappa}{m_b} = (20.3 \pm 1.0)\,\mathrm{MeV}$$

Remind you that all the parameters are the same as in the light baryon sector except for the hyperfine interaction.

Gh.S. Yang, HChK, M. Polyakov, M. Praszalowicz, PRD **94**, 071501(R) (2016)

Results for the charmed baryon masses

$\mathcal{R}_J^Q$	B_c	Mass	Experiment [17]	Deviation ξ_c
$\overline{\mathbf{3}}_{1/2}^c$	Λ_c	2272.5 ± 2.3	2286.5 ± 0.1	-0.006
	Ξ_c	2476.3 ± 1.2	2469.4 ± 0.3	0.003
$\mathbf{6}_{1/2}^c$	Σ_c	2445.3 ± 2.5	2453.5 ± 0.1	-0.003
	Ξ_c'	2580.5 ± 1.6	2576.8 ± 2.1	0.001
	Ω_c	2715.7 ± 4.5	2695.2 ± 1.7	0.008
$\mathbf{6}_{3/2}^c$	Σ_c^*	2513.4 ± 2.3	2518.1 ± 0.8	-0.002
	Ξ_c^*	2648.6 ± 1.3	2645.9 ± 0.4	0.001
	Ω_c^*	2783.8 ± 4.5	2765.9 ± 2.0	0.006

$$\xi_c = (M_{\rm th} - M_{\rm exp})/M_{\rm exp}$$

Gh.S. Yang, HChK, M. Polyakov, M. Praszalowicz, PRD **94**, 071501(R) (2016)

Results for the bottom baryon masses

$\mathcal{R}_J^Q$	B_b	Mass	Experiment [17]	Deviation ξ_b
$\overline{\mathbf{3}}_{1/2}^b$	Λ_b	5599.3 ± 2.4	5619.5 ± 0.2	-0.004
	Ξ_b	5803.1 ± 1.2	5793.1 ± 0.7	0.002
$\mathbf{6}_{1/2}^b$	Σ_b	5804.3 ± 2.4	5813.4 ± 1.3	-0.002
	Ξ_b'	5939.5 ± 1.5	5935.0 ± 0.05	0.001
	Ω_b	6074.7 ± 4.5	6048.0 ± 1.9	0.004
$\mathbf{6}_{3/2}^b$	Σ_b^*	5824.6 ± 2.3	5833.6 ± 1.3	-0.002
	Ξ_b^*	5959.8 ± 1.2	5955.3 ± 0.1	0.001
	Ω_b^*	6095.0 ± 4.4	$-$	$-$

The results are in remarkable agreement with the experimental data.

$$\xi_b = (M_{\rm th} - M_{\rm exp})/M_{\rm exp}$$

Gh.S. Yang, HChK, M. Polyakov, M. Praszalowicz, PRD **94**, 071501(R) (2016)

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Prediction from the present work

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Gh.S. Yang, HChK, M. Polyakov, M. Praszalowicz, PRD **94**, 071501(R) (2016)

Strong decay rates

- Collective operator for the strong vertices in SU(3) symmetric case

$$\mathcal{O}_\varphi = \frac{3}{M_1+M_2}\sum_{i=1,2,3}\left[G_0 D^{(8)}_{\varphi\, i} - G_1\, d_{ibc} D^{(8)}_{\varphi\, b}\hat{S}_c - G_2\frac{1}{\sqrt{3}}D^{(8)}_{\varphi\, 8}\hat{S}_i\right] p_i$$

- Decay widths

$$\Gamma_{B_1\to B_2+\varphi} = \frac{1}{2\pi}\overline{\langle B_2\,|\mathcal{O}_\varphi|\,B_1\rangle^2}\frac{M_2}{M_1}p$$

$$G_0 = -\frac{M+M'}{6f_\varphi}a_1$$

$$G_{1,2} = \frac{M+M'}{6f_\varphi}a_{2,3}$$

a_1	a_2	a_3
-3.509 ± 0.011	3.437 ± 0.028	0.604 ± 0.030

G. Yang and HChK, PRC **92**, 035206 (2015)

No additional free parameter!

$$f_\pi = 93\,\mathrm{MeV}, \quad f_K = 1.2 f_\pi$$

- These parameters a_i have been determined by the hyperon semileptonic decays.

HChK, Polyakov, Praszalowicz, Yang, PRD, D96, 094021 (2017).

Strong decays of heavy baryons

- Decay widths of the **charmed** baryon sextet

decay	this work	exp.
$\Sigma_c^{++}(\mathbf{6}_1,1/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{+}$	1.93	$1.89^{+0.09}_{-0.18}$
$\Sigma_c^{+}(\mathbf{6}_1,1/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{0}$	2.24	<4.6
$\Sigma_c^{0}(\mathbf{6}_1,1/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{-}$	1.90	$1.83^{+0.11}_{-0.19}$
$\Sigma_c^{++}(\mathbf{6}_1,3/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{+}$	14.47	$14.78^{+0.30}_{-0.19}$
$\Sigma_c^{+}(\mathbf{6}_1,3/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{0}$	15.02	<17
$\Sigma_c^{0}(\mathbf{6}_1,3/2)\to\Lambda_c^{+}(\overline{\mathbf{3}}_0,1/2)+\pi^{-}$	14.49	$15.3^{+0.4}_{-0.5}$
$\Xi_c^{+}(\mathbf{6}_1,3/2)\to\Xi_c(\overline{\mathbf{3}}_0,1/2)+\pi$	2.35	2.14 ± 0.19
$\Xi_c^{0}(\mathbf{6}_1,3/2)\to\Xi_c(\overline{\mathbf{3}}_0,1/2)+\pi$	2.53	2.35 ± 0.22

Experimental data are taken from the PDG RPP 2019.

No additional free parameter!

HChK, Polyakov, Praszalowicz, Yang, PRD, D96, 094021 (2017).

Strong decays of heavy baryons

- Decay widths of the **bottom** baryon sextet

decay	this work	exp.
$\Sigma_b^+(\mathbf{6}_1, 1/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0, 1/2) + \pi^+$	6.12	5.0 ± 0.5
$\Sigma_b^-(\mathbf{6}_1, 1/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0, 1/2) + \pi^-$	6.12	5.3 ± 0.5
$\Xi_b'(\mathbf{6}_1, 1/2) \to \Xi_c(\overline{\mathbf{3}}_0, 1/2) + \pi$	0.07	< 0.08
$\Sigma_b^+(\mathbf{6}_1, 3/2) \to \Lambda_b^0(\overline{\mathbf{3}}_0, 1/2) + \pi^+$	10.96	9.4 ± 0.5
$\Sigma_b^-(\mathbf{6}_1, 3/2) \to \Lambda_c^0(\overline{\mathbf{3}}_0, 1/2) + \pi^-$	11.77	10.4 ± 0.8
$\Xi_b^0(\mathbf{6}_1, 3/2) \to \Xi_b(\overline{\mathbf{3}}_0, 1/2) + \pi$	0.80	0.90 ± 0.18
$\Xi_b^-(\mathbf{6}_1, 3/2) \to \Xi_b(\overline{\mathbf{3}}_0, 1/2) + \pi$	1.28	1.65 ± 0.33

Experimental data are taken from the PDG 2019.
Note that the data was changed from the PDG 2016.

No additional free parameter!

HChK, Polyakov, Praszalowicz, Yang, PRD, D96, 094021 (2017).

Magnetic moment and radiative transitions

- Transition magnetic moments as matrix elements of the EM current

$$\mu \sim \frac{1}{2}\langle B'_Q|\boldsymbol{r}\times\boldsymbol{J}|B_Q\rangle \qquad J_i = \overline{q}\gamma_i q$$

- Collective operators based on the XQSM

$$\hat{\mu}^{(0)} = w_1 D^{(8)}_{\mathcal{Q}3} + w_2 d_{pq3} D^{(8)}_{\mathcal{Q}p}\cdot \hat{J}_q + \frac{w_3}{\sqrt{3}} D^{(8)}_{\mathcal{Q}8}\hat{J}_3,$$

$$\hat{\mu}^{(1)} = \frac{w_4}{\sqrt{3}} d_{pq3} D^{(8)}_{\mathcal{Q}p} D^{(8)}_{8q} + w_5\left(D^{(8)}_{\mathcal{Q}3}D^{(8)}_{88} + D^{(8)}_{\mathcal{Q}8}D^{(8)}_{83}\right) + w_6\left(D^{(8)}_{\mathcal{Q}3}D^{(8)}_{88} - D^{(8)}_{\mathcal{Q}8}D^{(8)}_{83}\right).$$

Gh.-S. Yang and HChK, Phys. Lett. B781 (2018) 601

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$$\hat{\mu}^{(1)} = \frac{w_4}{\sqrt{3}} d_{pq3} D^{(8)}_{\mathcal{Q}p} D^{(8)}_{8q} + w_5\left(D^{(8)}_{\mathcal{Q}3}D^{(8)}_{88} + D^{(8)}_{\mathcal{Q}8}D^{(8)}_{83}\right) + w_6\left(D^{(8)}_{\mathcal{Q}3}D^{(8)}_{88} - D^{(8)}_{\mathcal{Q}8}D^{(8)}_{83}\right).$$

They were already determined in the light baryon sector.

$$\overline{w}_i = \frac{(N_c-1)}{N_c} w_i, \quad i = 4,\ 5,\ 6.$$ (Nc should be replaced by (Nc-1))!

Gh.-S. Yang and HChK, Phys. Lett. B781 (2018) 601

Parameters

- Numerical values of the dynamical parameters were fixed by using the experimental data on the magnetic moments of the baryon octet.

- Numerical values of the parameters

$$\tilde{w}_1 = -10.08 \pm 0.24,$$
$$w_2 = 4.15 \pm 0.93,$$
$$w_3 = 8.54 \pm 0.86,$$
$$\overline{w}_4 = -2.53 \pm 0.14,$$
$$\overline{w}_5 = -3.29 \pm 0.57,$$
$$\overline{w}_6 = -1.34 \pm 0.56.$$

No free parameter to play.

Gh.-S. Yang and HChK, Phys. Lett. B781 (2018) 601

Magnetic moments

- Results of the magnetic moments of the baryon sextet with spin 1/2

$\mu\left[6_1^{1/2}, B_c\right]$	$\mu^{(0)}$	$\mu^{(\text{total})}$	Oh et al. [17]	Scholl and Weigel [18]	Faessler et al. [19]	Lattice QCD [20,22]
Σ_c^{++}	2.00 ± 0.09	2.15 ± 0.1	1.95	2.45	1.76	2.220 ± 0.505
Σ_c^{+}	0.50 ± 0.02	0.46 ± 0.03	0.41	0.25	0.36	–
Σ_c^{0}	-1.00 ± 0.05	-1.24 ± 0.05	-1.1	-1.96	-1.04	-1.073 ± 0.269
$\Xi_c^{\prime +}$	0.50 ± 0.02	0.60 ± 0.02	0.77	–	0.47	0.315 ± 0.141
$\Xi_c^{\prime 0}$	-1.00 ± 0.05	-1.05 ± 0.04	-1.12	–	-0.95	-0.599 ± 0.071
Ω_c^{0}	-1.00 ± 0.05	-0.85 ± 0.05	-0.79	–	-0.85	-0.688 ± 0.031

Magnetic moments

- Results of the magnetic moments of the baryon sextet with spin 3/2

$\mu\left[6_1^{3/2},\ B_c\right]$	$\mu^{(0)}$	$\mu^{(\mathrm{total})}$	Oh et al. [17]	Lattice QCD [21]
Σ_c^{*++}	3.00 ± 0.14	3.22 ± 0.15	3.23	–
Σ_c^{*+}	0.75 ± 0.04	0.68 ± 0.04	0.93	–
Σ_c^{*0}	-1.50 ± 0.07	-1.86 ± 0.07	-1.36	–
Ξ_c^{*+}	0.75 ± 0.04	0.90 ± 0.04	1.46	–
Ξ_c^{*0}	-1.50 ± 0.07	-1.57 ± 0.06	-1.4	–
Ω_c^{*0}	-1.50 ± 0.07	-1.28 ± 0.08	-0.87	-0.730 ± 0.023

No additional free parameter!

Transition magnetic moments

For Charmed Baryons

$B_c \to B'_c$	$\mu^{(0)}[\mu_N]$	$\mu^{(\text{total})}\ [\mu_N]$	[16–19]	[21]	[24, 25]	[32]	[35]	[45]	[46]	[37, 38]
$\Sigma_c^+ \to \Lambda_c^+$	1.24 ± 0.05	1.54 ± 0.06	1.63	–	-1.5 ± 0.4	-1.38 ± 0.02	1.56	-1.67	-2.26	
$\Xi_c'^+ \to \Xi_c^+$	-1.24 ± 0.05	-1.19 ± 0.06	1.56	–	–	0.73(input)	1.30	–	–	2.036
$\Xi_c'^0 \to \Xi_c^0$	0	0.21 ± 0.03	-0.07	–	–	0.22	-0.31	–	–	0.039
$\Sigma_c^{*+} \to \Lambda_c^+$	-1.76 ± 0.08	-2.18 ± 0.08	2.2	1.70	2.00 ± 0.53	2.00	2.40	–	–	
$\Xi_c^{*+} \to \Xi_c^+$	1.76 ± 0.08	1.69 ± 0.08	2.03	1.50	1.93 ± 0.72	1.05	2.08	–	–	
$\Xi_c^{*0} \to \Xi_c^0$	0	-0.29 ± 0.04	-0.33	-0.22	0.22 ± 0.07	-0.31	-0.50	–	–	
$\Sigma_c^{*++} \to \Sigma_c^{++}$	1.42 ± 0.07	1.52 ± 0.07	1.39	0.91	1.33 ± 0.38	1.07 ± 0.23	-1.37	–	–	
$\Sigma_c^{*+} \to \Sigma_c^+$	0.35 ± 0.02	0.33 ± 0.02	0.07	-0.06	0.57 ± 0.09	0.19 ± 0.06	-0.003	–	–	
$\Sigma_c^{*0} \to \Sigma_c^0$	-0.71 ± 0.03	-0.87 ± 0.03	-1.24	-1.03	0.24 ± 0.05	-0.69 ± 0.1	1.48	–	–	
$\Xi_c^{*+} \to \Xi_c'^+$	0.35 ± 0.02	0.43 ± 0.02	0.09	-0.09	–	0.23 ± 0.06	-0.23	–	–	
$\Xi_c^{*0} \to \Xi_c'^0$	-0.71 ± 0.03	-0.74 ± 0.03	-1.07	-0.92	–	-0.59 ± 0.12	1.24	–	–	
$\Omega_c^{*0} \to \Omega_c^0$	-0.71 ± 0.03	-0.60 ± 0.04	-0.94	-0.84	–	-0.49 ± 0.14	0.96	–	–	0.658

[16-19] Quark M
[21] Modified bag M
[24,25] LC QCD sum rules
[32] XPT
[35] XCQM
[45] Skyrme M I
[45] Skyrme M II
[37, 38] Lattice QCD

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Transition magnetic moments

For Bottom Baryons

$B_b \to B'_b$	$\mu^{(0)}[\mu_N]$	$\mu^{(\text{total})}[\mu_N]$	[16–19]	[21]	[24, 25]	[32]	[46]	[45]
$\Sigma_b^0 \to \Lambda_b^0$	-1.24 ± 0.05	-1.54 ± 0.06	–	–	–	-1.37	-2.24	-1.54
$\Xi_b'^0 \to \Xi_b^0$	1.24 ± 0.05	1.19 ± 0.06	–	–	–	-0.75	–	–
$\Xi_b'^- \to \Xi_b^-$	0	-0.21 ± 0.03	–	–	–	0.21	–	–
$\Sigma_b^{*0} \to \Lambda_b^0$	-1.76 ± 0.08	-2.18 ± 0.08	2.28	1.49	1.52 ± 0.58	1.96	–	–
$\Xi_b^{*0} \to \Xi_b^0$	1.76 ± 0.08	1.69 ± 0.08	2.03	1.32	1.71 ± 0.60	1.06	–	–
$\Xi_b^{*-} \to \Xi_b^-$	0	-0.29 ± 0.04	-0.26	-0.14	0.18 ± 0.06	-0.30	–	–
$\Sigma_b^{*+} \to \Sigma_b^+$	-1.42 ± 0.07	-1.52 ± 0.07	1.81	1.19	0.83 ± 0.25	1.17 ± 0.22	–	–
$\Sigma_b^{*0} \to \Sigma_b^0$	-0.35 ± 0.02	-0.33 ± 0.02	0.49	0.35	0.20 ± 0.08	0.30 ± 0.06	–	–
$\Sigma_b^{*-} \to \Sigma_b^-$	0.71 ± 0.03	0.87 ± 0.03	-0.82	-0.50	0.42 ± 0.14	-0.58 ± 0.1	–	–
$\Xi_b^{*0} \to \Xi_b'^0$	-0.35 ± 0.02	-0.43 ± 0.02	0.61	0.39	–	0.33 ± 0.06	–	–
$\Xi_b^{*-} \to \Xi_b'^-$	0.71 ± 0.03	0.74 ± 0.03	-0.66	-0.42	–	-0.49 ± 0.1	–	–
$\Omega_b^{*-} \to \Omega_b^-$	0.71 ± 0.03	0.60 ± 0.04	-0.52	-0.34	–	-0.38 ± 0.13	–	–

Except for the sign, they are the same as in the charmed baryons
in the infinitely heavy quark mass limit.

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Radiative decay rates

$$\Gamma(B_{1/2} \to B'_{1/2}\gamma) = 4\alpha_{\mathrm{EM}} \frac{E_\gamma^3}{(M_{B'_{1/2}} + M_{B_{1/2}})^2} \left(\frac{\mu_{B'_{1/2}B_{1/2}}}{\mu_N}\right)^2,$$

$$\Gamma(B_{3/2} \to B'_{1/2}\gamma) = \frac{\alpha_{\mathrm{EM}}}{2} \frac{E_\gamma^3}{M_{B'_{1/2}}^2} \left(\frac{\mu_{B'_{1/2}B_{3/2}}}{\mu_N}\right)^2,$$

- E2 moments were ignored, because they are negligibly tiny.

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Results for radiative decay rates

For Charmed Baryons

$B_c \to B'_c\,\gamma$	$\Gamma_\gamma^{(0)}$ [keV]	$\Gamma_\gamma^{(\mathrm{total})}$ [keV]	[21]	[25]	[32]	[37, 38]
$\Sigma_c^+ \to \Lambda_c^+\,\gamma$	8.32 ± 0.73	12.82 ± 0.95	–	–	65.6 ± 2	–
$\Xi_c'^+ \to \Xi_c^+\,\gamma$	2.18 ± 0.20	2.02 ± 0.20	–	–	5.43 ± 0.33	5.468
$\Xi_c'^0 \to \Xi_c^0\,\gamma$	0	0.06 ± 0.01	–	–	0.46	0.002
$\Sigma_c^{*+} \to \Lambda_c^+\,\gamma$	23.04 ± 2.12	35.49 ± 2.81	21.61	29.90	161.6 ± 5	–
$\Xi_c^{*+} \to \Xi_c^+\,\gamma$	9.34 ± 0.82	8.66 ± 0.81	6.82	11.29	21.6 ± 1	–
$\Xi_c^{*0} \to \Xi_c^0\,\gamma$	0	0.25 ± 0.06	0.14	0.14	1.84	–
$\Sigma_c^{*++} \to \Sigma_c^{++}\,\gamma$	0.31 ± 0.03	0.36 ± 0.03	0.13	0.28	1.20 ± 0.6	–
$\Sigma_c^{*+} \to \Sigma_c^+\,\gamma$	0.02 ± 0.003	0.02 ± 0.003	0.001	0.05	0.04 ± 0.03	–
$\Sigma_c^{*0} \to \Sigma_c^0\,\gamma$	0.08 ± 0.01	0.12 ± 0.01	0.17	0.01	0.49 ± 0.1	–
$\Xi_c^{*+} \to \Xi_c'^+\,\gamma$	0.02 ± 0.002	0.03 ± 0.003	0.001	–	0.07 ± 0.03	–
$\Xi_c^{*0} \to \Xi_c'^0\,\gamma$	0.08 ± 0.01	0.09 ± 0.01	0.14	–	0.42 ± 0.16	–
$\Omega_c^{*0} \to \Omega_c^0\,\gamma$	0.09 ± 0.01	0.06 ± 0.01	0.12	–	0.32 ± 0.20	0.074

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Results for radiative decay rates

For Bottom Baryons

$B_b \to B_b' \gamma$	$\Gamma_\gamma^{(0)}$ [keV]	$\Gamma_\gamma^{(\text{total})}$ [keV]	[21]	[25]	[32]
$\Sigma_b^0 \to \Lambda_b^0 \gamma$	2.4 ± 0.2	3.7 ± 0.3	–	–	108.0 ± 4
$\Xi_b'^0 \to \Xi_b^0 \gamma$	0.93 ± 0.08	0.87 ± 0.08	–	–	13.0 ± 0.8
$\Xi_b'^- \to \Xi_b^- \gamma$	0	0.02 ± 0.01	–	–	1.0
$\Sigma_b^{*0} \to \Lambda_b^0 \gamma$	3.3 ± 0.3	5.1 ± 0.4	2.38	2.48	142.1 ± 5
$\Xi_b^{*0} \to \Xi_b^0 \gamma$	1.3 ± 0.1	1.2 ± 0.1	0.72	1.20	17.2 ± 0.1
$\Xi_b^{*-} \to \Xi_b^- \gamma$	0	0.03 ± 0.01	0.01	0.01	1.4
$\Sigma_b^{*+} \to \Sigma_b^+ \gamma$	0.0020	0.0022	0.0014	0.0007	50 ± 20
$\Sigma_b^{*0} \to \Sigma_b^0 \gamma$	0.0001	0.0001	0.0001	0.00004	3.0 ± 1
$\Sigma_b^{*-} \to \Sigma_b^- \gamma$	0.0004	0.0010	0.0002	0.0001	10.3 ± 4
$\Xi_b^{*0} \to \Xi_b'^0 \gamma$	0.00004	0.0001	0.00005	–	1.5 ± 0.5
$\Xi_b^{*-} \to \Xi_b'^- \gamma$	0.0004	0.0005	0.0001	–	8.2 ± 4
$\Omega_b^{*-} \to \Omega_b^- \gamma$	0.006 ± 0.001	0.004 ± 0.001	0.0013	–	30.6 ± 26

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Summary & Conclusion

- A pion mean-field approach (XQSM) describes both the light and singly-heavy baryons in a consistent way.
- A singly-heavy baryon consists of Nc-1 valence quarks bound by the pion mean fields, while a heavy quark is considered as a mere static color source in the limit of the infinitely heavy-quark mass.
- We first computed the mass spectra of the lowest-lying heavy baryons.
- Strong decay rates were studied without any free parameter.
- We investigated the magnetic and transition magnetic moments (No additional free parameters!)

Though this be madness, yet there is method in it.

Hamlet Act 2, Scene 2

by Shakespeare

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