The missing resonance problem

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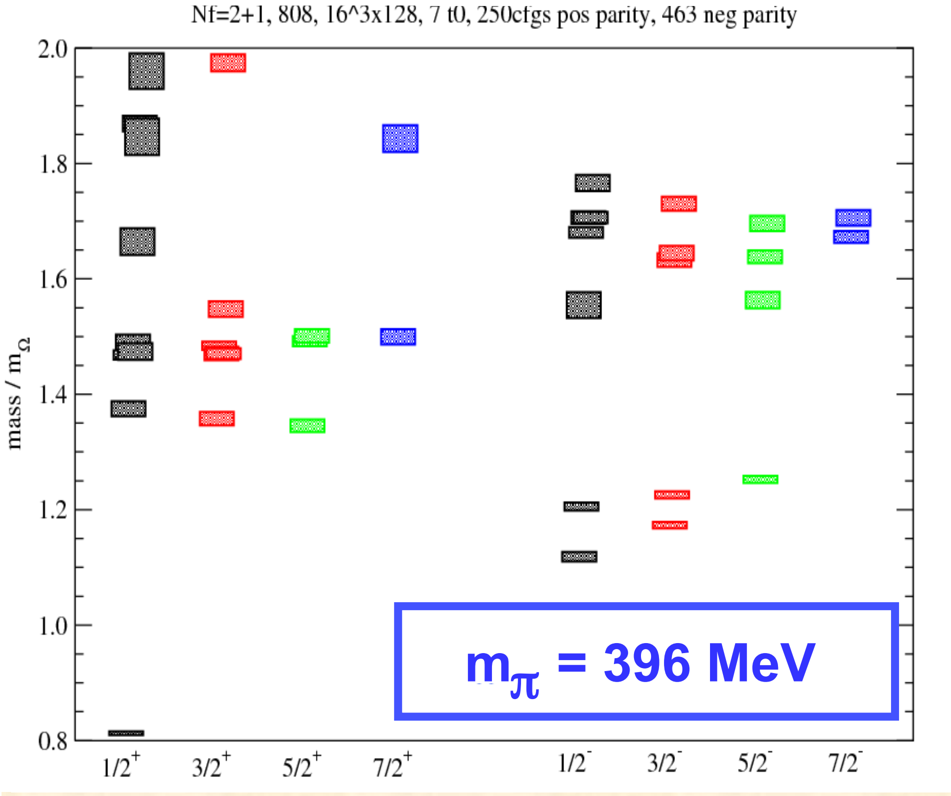
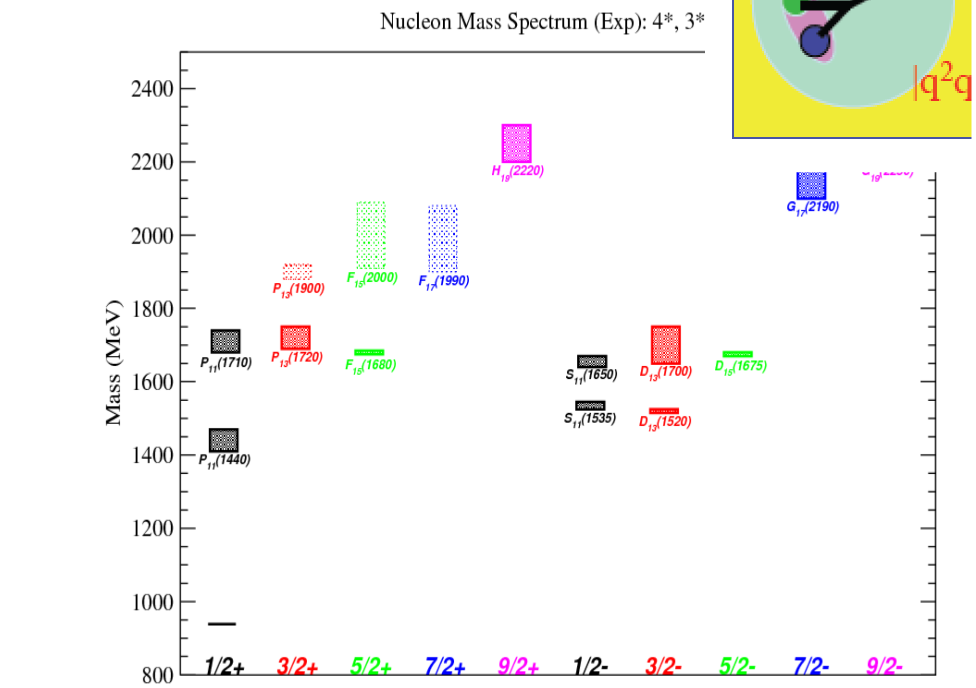
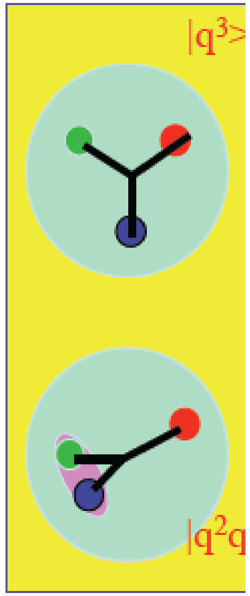
N* SPECTRUM

"Missing resonance problem"

- What are collective modes?
- What is the structure of the states?

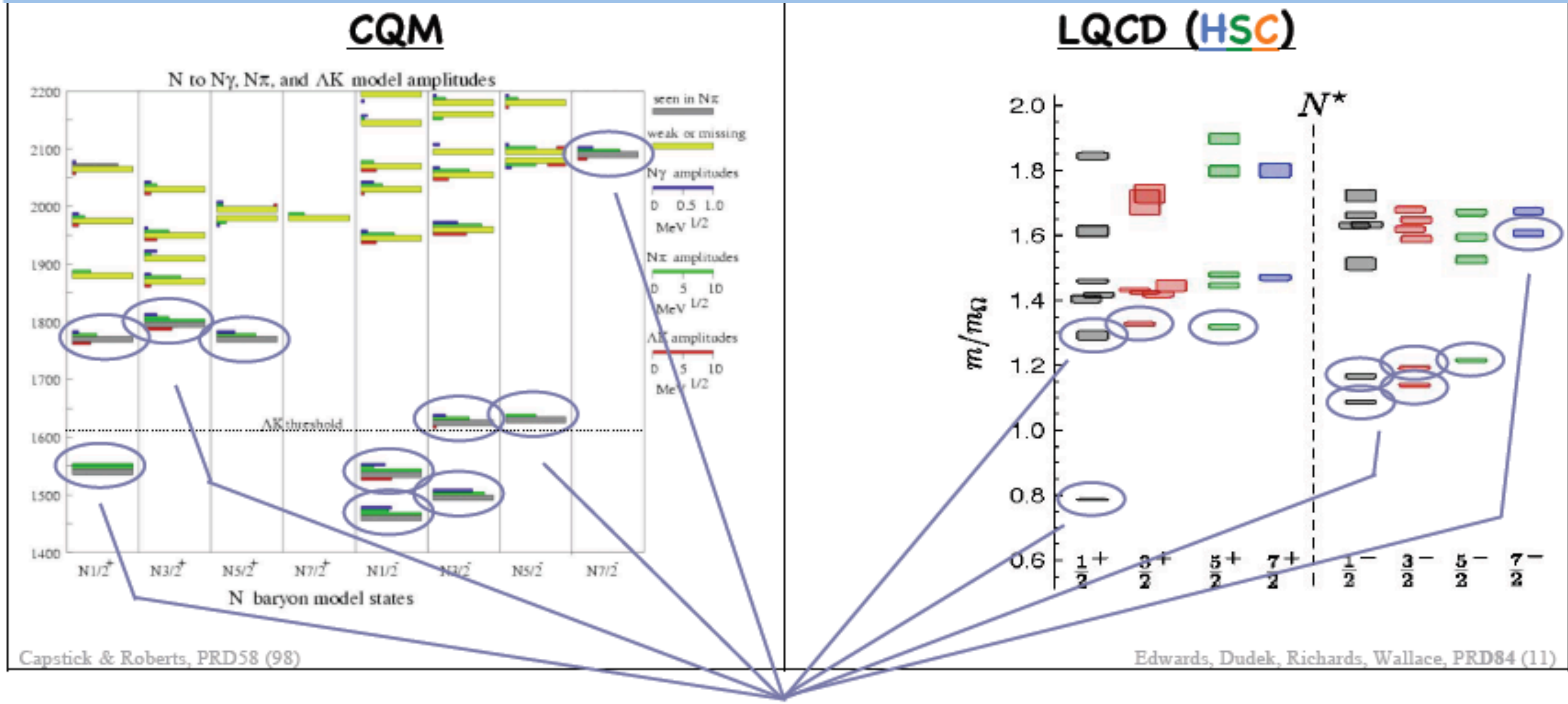






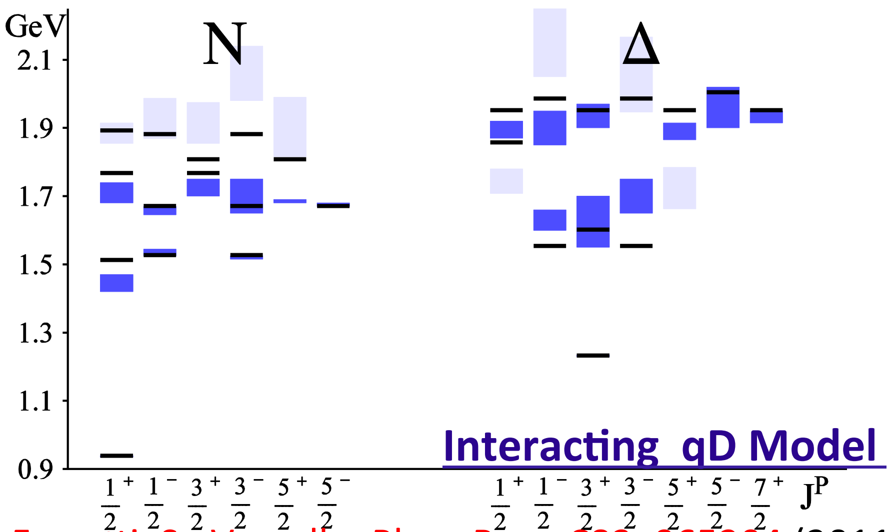
Dudek et al.

Experiment



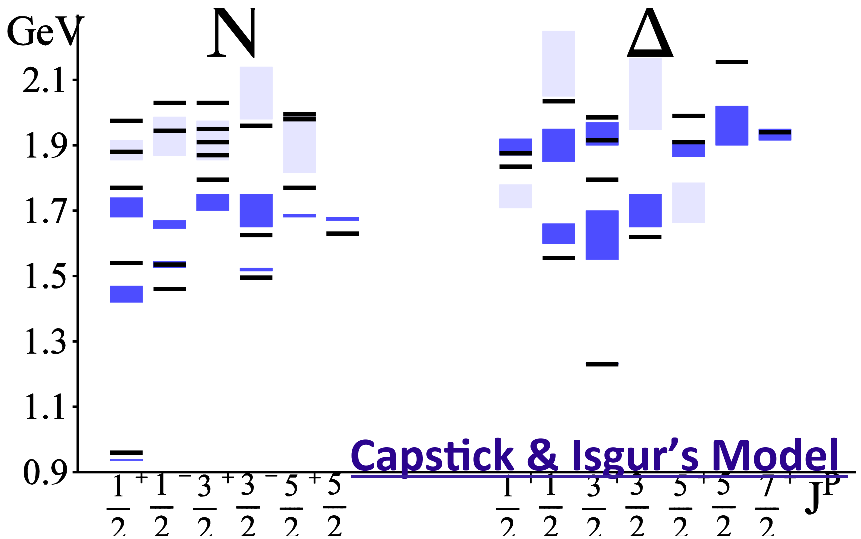
- only lowest few in each band seen (in πN) with 4★ or 3★ status
- higher levels predicted to have larger couplings to KΛ, KΣ, ππN, …
- large number of unobserved levels ⇔ caveat: ignoring qq correlations

Non-strange baryons. Complete spectrum



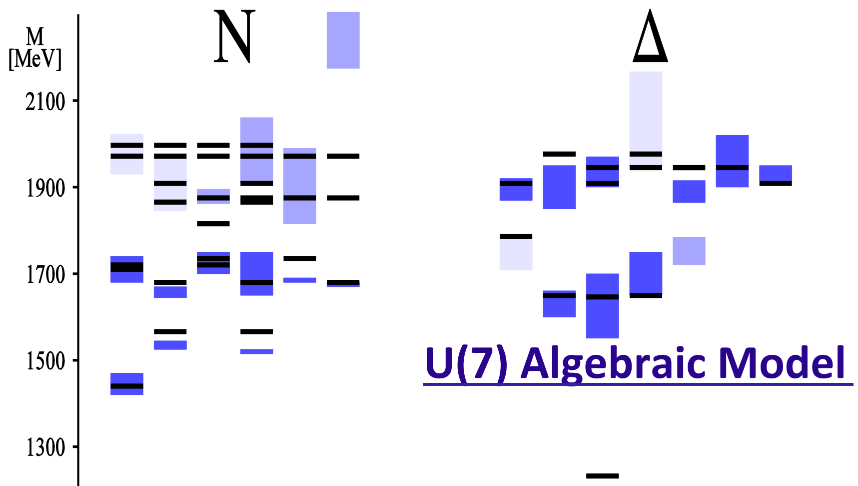
Ferretti, S., Vassallo ,Phys. Rev.. C83, 065204 (2011)
E.S.,Phys. Rev. C 72, 022201(R) (2005).

0 missing resonances



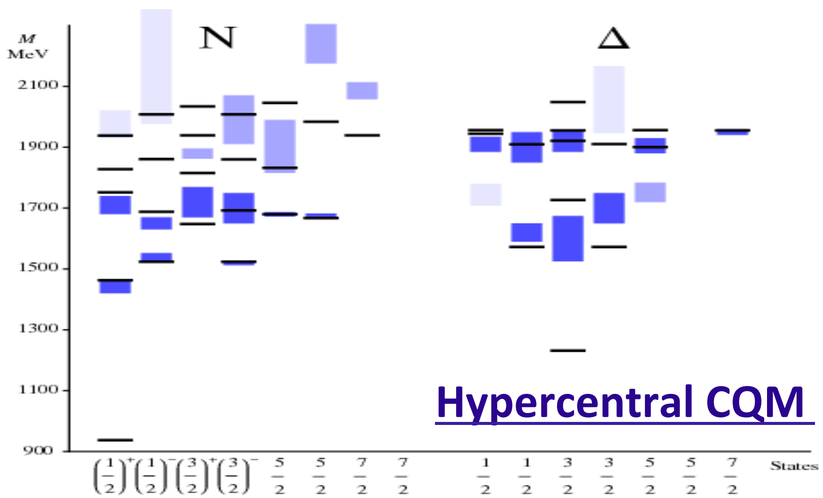
Capstick and Isgur, *Phys. Rev. D34, 2809.*

8 missing resonances



Bijker, Iachello and Leviatan, *Annals Phys. 236, 69.*

18 missing resonances



Giannini, Santopinto, Vassallo, *Eur. Phys. J .A12:447*

9 missing resonances

The Interacting Quark Diquark Model

Missing resonance problem

- States predicted by quark models with no corresponding experimental counterparts
- QMs predict eccessive number of states
- Possible explanations:
  1) Some baryon states may be very weakly coupled to single-pion channels. Look for two-pion, three-pion, eta decay channels …
  2) Consider models based on smaller number of effective degrees of freedom (like quark-diquark model): number of missing states decreases notably

Evidences of diquark correlations

- **Regge behavior of hadrons**

  Baryons arranged in rotational Regge trajectories ($J=\alpha+\alpha' M2$) with the same slope of the mesonic ones.

- **Δ I = ½ rule in weak nonleptonic decays**

  Neubert and Stech, Phys. Lett. B **231** (1989) 477; Phys. Rev. D **44** (1991) 775

- **Regularities in parton distribution functions and in spin-dependent structure functions**

  Close and Thomas, Phys. Lett. B **212** (1988) 227

- **Regularities in Λ(1116) and Λ(1520) fragmentation functions**

  Jaffe, Phys. Rept. **409** (2005) 1 [Nucl. Phys. Proc. Suppl. **142** (2005) 343]
  Wilczek, hep-ph/0409168

- **Any interaction that binds π and ρ mesons in the rainbow-ladder approximation of the DSE will produce diquarks**

  Cahill, Roberts and Praschifka, Phys. Rev. D **36** (1987) 2804

- **Indications of diquark confinement**

  Bender, Roberts and Von Smekal, Phys. Lett. B **380** (1996) 7

Interacting qD model

E. Santopinto, PRC72, 022201 (2005)

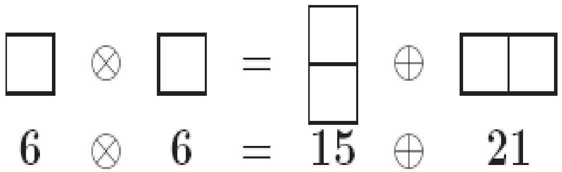
I part:Construction of the states

▪ Diquark

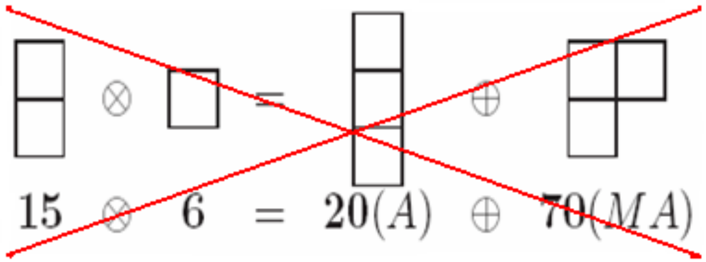
- Two correlated quarks in S wave:symm.

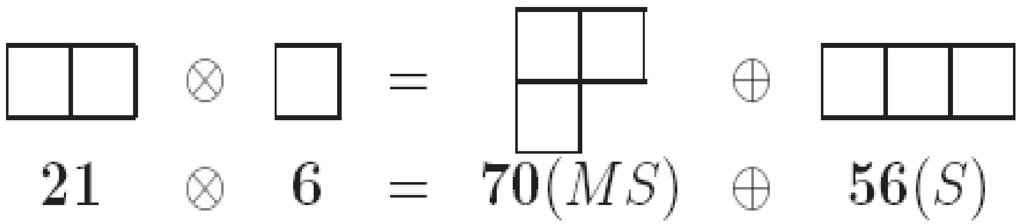
- Baryon in 1_c color representazion → diquark in bar-3_c (A)

- Diquark WF: Ψ_D spin-flavor part symm. → 15 (A) repr. not present



- SU(6)$_{sf}$ representations for baryons





- Problem of missing resonances

Scalar & axial-vector diquarks

▪ 21 $SU(6)_{sf}$ representation

- Decomposed in $SU(2)_s$ x $SU(3)_f$
- [bar-3,0] & [6,1] representations. Notation: [flavor,spin]

• "Good" & "bad" diquarks

- According to OGE-calculations, [bar-3,0] is energetically favored [Wilczek, Jaffe]
- [bar 3,0]: good (scalar) diquark
- [6,1]: bad (axial-vector) diquark

the Interacting qD model

E. Santopinto, PRC72, 022201 (2005)

- **Hamiltonian**

$$H = \frac{p^2}{2m} - \frac{\tau}{r} + \beta r + [B\delta_{S_{12},1} + C\delta_0] +$$

$$+ (-1)^{l+1} 2Ae^{-\alpha r}[(\vec{s}_{12} \cdot \vec{s}_3) + (\vec{t}_{12} \cdot \vec{t}_3) + (\vec{s}_{12} \cdot \vec{s}_3)(\vec{t}_{12} \cdot \vec{t}_3)]$$

- **Non-rel. Kinetic energy + Coulomb + linear confining terms**
- **Splitting between scalar & axial-vector diquarks**
- **Exchange potential**
-

Baryon $L_{2I,2J}$	Status	Mass (MeV)	J^p	$M_{\rm cal}$ (MeV)
$N(939)P_{11}$	****	939	$1/2^+$	940
$N(1440)P_{11}$	****	1410-1450	$1/2^+$	1538
$N(1520)D_{13}$	****	1510-1520	$3/2^-$	1543
$N(1535)S_{11}$	****	1525-1545	$1/2^-$	1538
$N(1650)S_{11}$	****	1645-1670	$1/2^-$	1673
$N(1675)D_{15}$	****	1670-1680	$5/2^-$	1673
$N(1680)F_{15}$	****	1680-1690	$5/2^+$	1675
$N(1700)D_{13}$	***	1650-1750	$3/2^-$	1673
$N(1710)P_{11}$	***	1680-1740	$1/2^+$	1640
$N(1720)P_{13}$	****	1700-1750	$3/2^+$	1675
$N(1860)F_{15}$	**	1820-1960	$5/2^+$	1975
$N(1875)D_{13}$	***	1820-1920	$3/2^-$	1838
$N(1880)P_{11}$	**	1835-1905	$1/2^+$	1838
$N(1895)S_{11}$	**	1880-1910	$1/2^-$	1838
$N(1900)P_{13}$	***	1875-1935	$3/2^+$	1967
$N(1990)F_{17}$	**	1995-2125	$7/2^+$	2015
$N(2000)F_{15}$	**	1950-2150	$5/2^+$	2015
$N(2040)P_{13}$	*	2031-2065	$3/2^+$	2015
$N(2060)D_{15}$	**	2045-2075	$5/2^-$	2078
$N(2100)P_{11}$	**	2050-2200	$1/2^+$	2015
$N(2120)D_{13}$	**	2090-2210	$3/2^-$	2069

Rel. Interacting qD model

J. Ferretti, E. Santopinto & A. Vassallo, PRC83, 065204 (2011)

- Relativistic extension of the previous model (point-form formalism).

$$M = E_0 + \sqrt{q^2 + m_1^2} + \sqrt{q^2 + m_2^2} + M_{\rm dir}(r) + M_{\rm cont}(r) + M_{\rm ex}(r),$$

$$M_{\rm dir}(r) = -\frac{\tau}{r}(1 - e^{-\mu r}) + \beta r.$$

$$M_{\rm ex}(r) = (-1)^{l+1} e^{-\sigma r} [A_S(\vec{s}_1 \cdot \vec{s}_2) + A_I(\vec{t}_1 \cdot \vec{t}_2) + A_{SI}(\vec{s}_1 \cdot \vec{s}_2)(\vec{t}_1 \cdot \vec{t}_2)],$$

$$M_{\rm cont} = \left(\frac{m_1 m_2}{E_1 E_2}\right)^{1/2+\epsilon} \frac{\eta^3 D}{\pi^{3/2}} e^{-\eta^2 r^2} \, \delta_{L,0}\delta_{s_1,1} \left(\frac{m_1 m_2}{E_1 E_2}\right)^{1/2+\epsilon}$$

- Numerical solution with variational program
- Parameters fitted to nonstrange baryon spectrum

Extension to strange baryons

- Mass formula

$$M = E_0 + \sqrt{q^2 + m_1^2} + \sqrt{q^2 + m_2^2} + M_{dir} + M_{ex} + M_{cont}$$

- Exchange potential is generalized to

  Gürsey-Radicati inspired interaction

$$M_{ex} = (-1)^{L+1} e^{-\sigma r} [A_s \vec{s}_1 \cdot \vec{s}_2 + A_I \vec{t}_1 \cdot \vec{t}_2 + A_F \vec{\lambda}_1 \cdot \vec{\lambda}_2]$$

- Results updated to most recent exp. data.

  Global fit to strange & nonstrange baryons

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

- **Parameters**

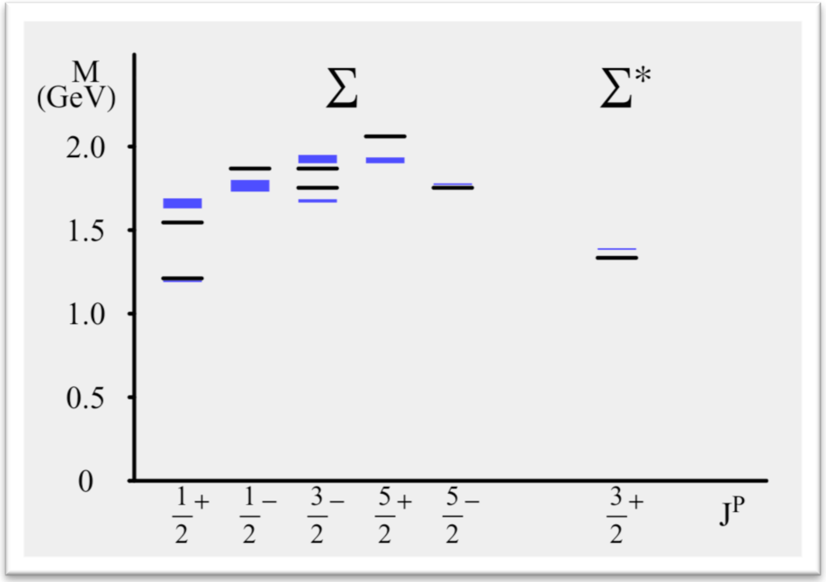
Parameter	Value (Fit 1)	Value (Fit 2)	Parameter	Value (Fit 1)	Value (Fit 2)
m_n	200 MeV	159 MeV	m_s	550 MeV	213 Mev
$m_{[n,n]}$	600 MeV	607 MeV	$m_{[n,s]}$	900 MeV	856 MeV
$m_{\{n,n\}}$	950 MeV	963 MeV	$m_{\{n,s\}}$	1200 MeV	1216 MeV
$m_{\{s,s\}}$	1580 MeV	1352 MeV	τ	1.20	1.02
μ	75.0 fm^{-1}	28.4 fm^{-1}	β	2.15 fm^{-2}	2.36 fm^{-2}
A_S	350 MeV	-436 MeV	A_F	100 MeV	193 MeV
A_I	250 MeV	791 MeV	σ	2.30 fm^{-1}	2.25 fm^{-1}
E_0	141 MeV	150 MeV	ϵ	0.37	–
D	6.13 fm^2	–	η	11.0 fm^{-1}	–

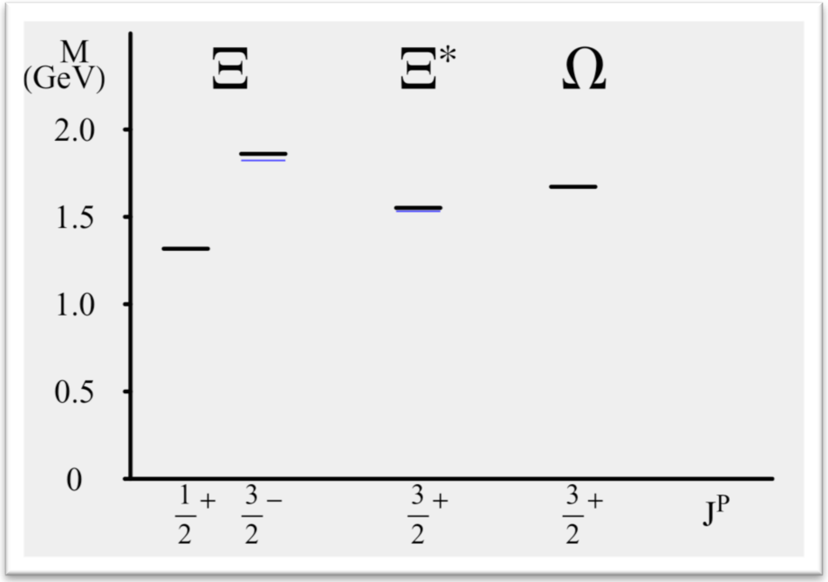
N spectrum and N(1900)P_{13}

Resonance	Status	$M^{exp.}$ (MeV)	J^P	L^P	S	s_1	n_r	$M^{calc.}$ (fit 1) (MeV)
$N(939)\ P_{11}$	****	939	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	0	939
$N(1440)\ P_{11}$	****	1420–1470	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	1	1511
$N(1520)\ D_{13}$	****	1515–1525	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	0	1537
$N(1535)\ S_{11}$	****	1525–1545	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	0	1537
$N(1650)\ S_{11}$	****	1645–1670	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	1	0	1625
$N(1675)\ D_{15}$	****	1670–1680	$\frac{5}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
$N(1680)\ F_{15}$	****	1680–1690	$\frac{5}{2}^+$	2^+	$\frac{1}{2}$	0	0	1799
$N(1700)\ D_{13}$	***	1650–1750	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	1	0	1625
$N(1710)\ P_{11}$	***	1680–1740	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	0	1776
$N(1720)\ P_{13}$	****	1700–1750	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	0	1648
Missing			$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
Missing	3 missing states		$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
Missing			$\frac{3}{2}^+$	2^+	$\frac{1}{2}$	0	0	1799
$N(1875)\ D_{13}$	***	1820–1920	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	1	1888
$N(1880)\ P_{11}$	**	1835–1905	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	2	1890
$N(1895)\ S_{11}$	**	1880–1910	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	1	1888
$N(1900)\ P_{13}$	***	1875–1935	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	1	1947

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

Σ, Σ*, Ξ, Ξ* and Ω spectrum

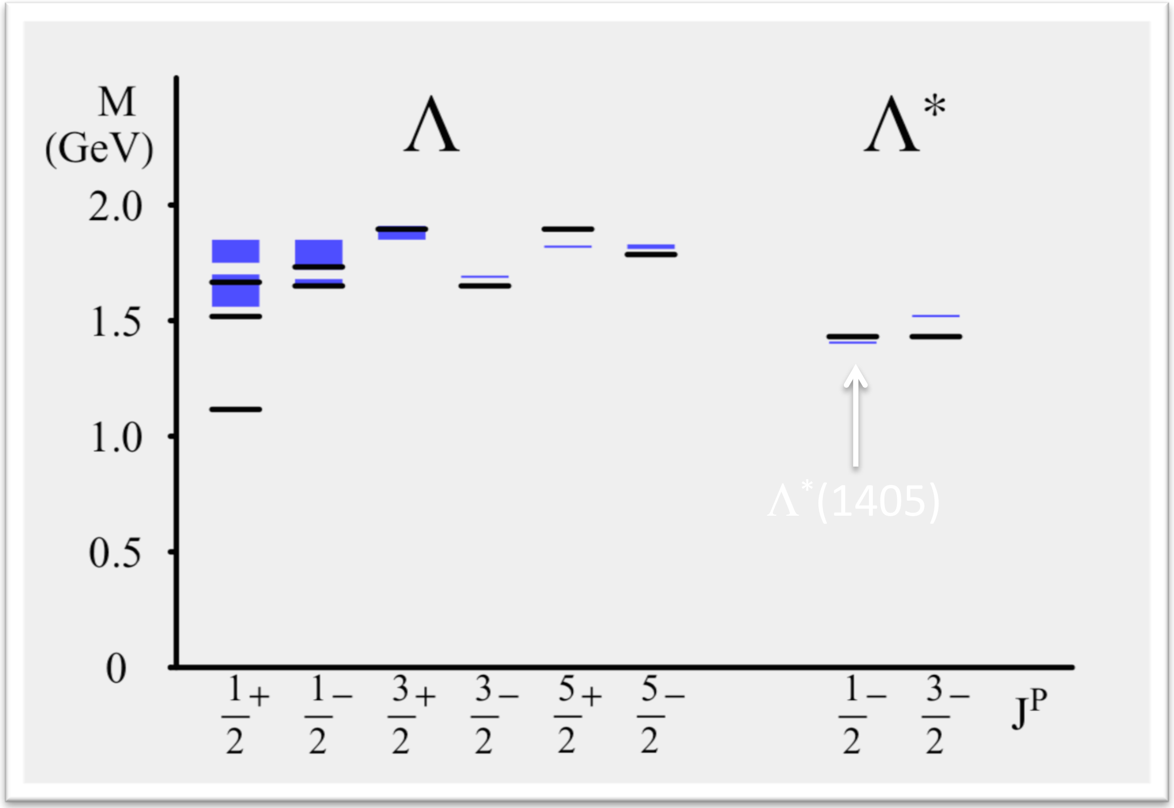




*** and **** PDG states below 2 GeV

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

Λ and Λ^* spectrum



*** and **** PDG states below 2 GeV

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

N spectrum and N(1900)P_{13}

Resonance	Status	$M^{\text{exp.}}$ (MeV)	J^P	L^P	S	s_1	n_r	$M^{\text{calc.}}$ (fit 1) (MeV)
$N(939)\ P_{11}$	****	939	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	0	939
$N(1440)\ P_{11}$	****	1420–1470	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	1	1511
$N(1520)\ D_{13}$	****	1515–1525	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	0	1537
$N(1535)\ S_{11}$	****	1525–1545	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	0	1537
$N(1650)\ S_{11}$	****	1645–1670	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	1	0	1625
$N(1675)\ D_{15}$	****	1670–1680	$\frac{5}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
$N(1680)\ F_{15}$	****	1680–1690	$\frac{5}{2}^+$	2^+	$\frac{1}{2}$	0	0	1799
$N(1700)\ D_{13}$	***	1650–1750	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	1	0	1625
$N(1710)\ P_{11}$	***	1680–1740	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	0	1776
$N(1720)\ P_{13}$	****	1700–1750	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	0	1648
Missing			$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
Missing			$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	0	1746
Missing			$\frac{3}{2}^+$	2^+	$\frac{1}{2}$	0	0	1799
$N(1875)\ D_{13}$	***	1820–1920	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	1	1888
$N(1880)\ P_{11}$	**	1835–1905	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	2	1890
$N(1895)\ S_{11}$	**	1880–1910	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	1	1888
$N(1900)\ P_{13}$	***	1875–1935	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	1	1947

3 missing states

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

Δ spectrum

Resonance	Status	$M^{exp.}$ (MeV)	J^P	L^P	S	s_1	n_r	$M^{calc.}$ (fit 1) (MeV)
$\Delta(1232)\ P_{33}$	****	1230–1234	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	0	1247
$\Delta(1600)\ P_{33}$	***	1500–1700	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	1	1689
$\Delta(1620)\ S_{31}$	****	1600–1660	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	1	0	1830
$\Delta(1700)\ D_{33}$	****	1670–1750	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	1	0	1830
$\Delta(1750)\ P_{31}$	*	1708–1780	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	0	1489
$\Delta(1900)\ S_{31}$	**	1840–1920	$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	0	1910
$\Delta(1905)\ F_{35}$	****	1855–1910	$\frac{5}{2}^+$	2^+	$\frac{3}{2}$	1	0	2042
$\Delta(1910)\ P_{31}$	****	1860–1920	$\frac{1}{2}^+$	2^+	$\frac{3}{2}$	1	0	1827
$\Delta(1920)\ P_{33}$	***	1900–1970	$\frac{3}{2}^+$	2^+	$\frac{3}{2}$	1	0	2042
$\Delta(1930)\ D_{35}$	***	1900–2000	$\frac{5}{2}^-$	1^-	$\frac{3}{2}$	1	0	1910
$\Delta(1940)\ D_{33}$	**	1940–2060	$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	0	1910
$\Delta(1950)\ F_{37}$	****	1915–1950	$\frac{7}{2}^+$	2^+	$\frac{3}{2}$	1	0	2042

No missing states below 2 GeV

Delta(1930) 3/2- well described, on the contrary it is a problem in 3quark models since it corresponds to higher shells

Σ and Σ^* spectrum

Resonance	Status	$M^{\text{exp.}}$ (MeV)	J^P	L^P	S	s_1	Q^2q	**F**	$\mathbf{F}_1$	I	t_1	n_r	$M^{\text{calc.}}$ (fit 2) (MeV)
$\Sigma(1193)\ P_{11}$	****	1189—1197	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	1	$\frac{1}{2}$	0	1211
$\Sigma(1620)\ S_{11}$	**	≈1620	$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1753
$\Sigma(1660)\ P_{11}$	***	1630–1690	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1546
$\Sigma(1670)\ D_{13}$	****	1665–1685	$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1753
$\Sigma(1750)\ S_{11}$	***	1730–1800	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	1	$\frac{1}{2}$	0	1868
$\Sigma(1770)\ P_{11}$	*	≈1770	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	$\{n,s\}n$	**8**	**6**	1	$\frac{1}{2}$	0	1668
$\Sigma(1775)\ D_{15}$	****	1770–1780	$\frac{5}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1753
$\Sigma(1880)\ P_{11}$	**	≈1880	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	1	$\frac{1}{2}$	1	1801
$\Sigma(1915)\ F_{15}$	****	1900–1935	$\frac{5}{2}^+$	2^+	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	1	$\frac{1}{2}$	0	2061
$\Sigma(1940)\ D_{13}$	***	1900–1950	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	1	$\frac{1}{2}$	0	1868
Missing	1 missing state		$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1895
$\Sigma(2000)\ S_{11}$	*	≈2000	$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,n\}s$	**8**	**6**	1	1	0	1895
$\Sigma^*(1385)\ P_{13}$	****	1382–1388	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{n,n\}s$	**10**	**6**	1	1	0	1334
$\Sigma^*(1840)\ P_{13}$	*	≈1840	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{n,s\}n$	**10**	**6**	1	$\frac{1}{2}$	0	1439
$\Sigma^*(2080)\ P_{13}$	**	≈2080	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{n,n\}s$	**10**	**6**	1	1	1	1924

Ξ, Ξ^* and Ω spectrum

Resonance	Status	$M^{\text{exp.}}$ (MeV)	J^P	L^P	S	s_1	Q^2q	**F**	$\mathbf{F}_1$	I	t_1	n_r	$M^{\text{calc.}}$ (fit 2) (MeV)
$\Xi(1318)\ P_{11}$	****	1315–1322	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]s$	**8**	$\bar{\mathbf{3}}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1317
Missing			$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	$\{n,s\}s$	**8**	**6**	$\frac{1}{2}$	$\frac{1}{2}$	0	1772
$\Xi(1820)\ D_{13}$	***	1818–1828	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]s$	**8**	$\bar{\mathbf{3}}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1861
Missing			$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]s$	**8**	$\bar{\mathbf{3}}$	$\frac{1}{2}$	$\frac{1}{2}$	1	1868
Missing			$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	$\{s,s\}n$	**8**	**6**	$\frac{1}{2}$	0	0	1874
Missing			$\frac{3}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,s\}s$	**8**	**6**	$\frac{1}{2}$	$\frac{1}{2}$	0	1971
$\Xi^*(1530)\ P_{13}$	****	1531–1532	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{n,s\}s$	**10**	**6**	$\frac{1}{2}$	$\frac{1}{2}$	0	1552
Missing			$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{s,s\}n$	**10**	**6**	$\frac{1}{2}$	0	0	1653
$\Omega(1672)\ P_{03}$	****	1672–1673	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{s,s\}s$	**10**	**6**	0	0	0	1672

5 missing states

Λ and Λ^* spectrum

Resonance	Status	$M^{exp.}$ (MeV)	J^P	L^P	S	s_1	Q^2q	**F**	$\mathbf{F}_1$	I	t_1	n_r	$M^{calc.}$ (fit 2) (MeV)
$\Lambda(1116)\ P_{01}$	****	1116	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	0	1116
$\Lambda(1600)\ P_{01}$	***	1560–1700	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	0	1518
$\Lambda(1670)\ S_{01}$	****	1660–1680	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	0	1650
$\Lambda(1690)\ D_{03}$	****	1685–1695	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	0	1650
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	0	1732
Missing			$\frac{1}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1785
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	1	1785
$\Lambda(1800)\ S_{01}$	***	1720–1850	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	0	1732
$\Lambda(1810)\ P_{01}$	***	1750–1850	$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	1	1666
$\Lambda(1820)\ F_{05}$	****	1815–1825	$\frac{5}{2}^+$	2^+	$\frac{1}{2}$	0	$[n,n]s$	**8**	$\bar{\mathbf{3}}$	0	0	0	1896
$\Lambda(1830)\ D_{05}$	****	1810–1830	$\frac{5}{2}^-$	1^-	$\frac{3}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1785
$\Lambda(1890)\ P_{03}$	****	1850–1910	$\frac{3}{2}^+$	0^+	$\frac{3}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1896
Missing			$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1955
Missing			$\frac{1}{2}^+$	0^+	$\frac{1}{2}$	0	$[n,s]n$	**8**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	1	1960
Missing			$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1969
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	1	$\{n,s\}n$	**8**	**6**	0	$\frac{1}{2}$	0	1969
$\Lambda^*(1405)\ S_{01}$	****	1402–1410	$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**1**	$\bar{\mathbf{3}}$	0	0	0	1431
$\Lambda^*(1520)\ D_{03}$	****	1519–1521	$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**1**	$\bar{\mathbf{3}}$	0	0	0	1431
Missing			$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**1**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	0	1443
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**1**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	0	1443
Missing			$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**1**	$\bar{\mathbf{3}}$	0	0	1	1854
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,n]s$	**1**	$\bar{\mathbf{3}}$	0	0	1	1854
Missing			$\frac{1}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**1**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	1	1928
Missing			$\frac{3}{2}^-$	1^-	$\frac{1}{2}$	0	$[n,s]n$	**1**	$\bar{\mathbf{3}}$	0	$\frac{1}{2}$	1	1928

13 missing states

SANTOPINTO AND FERRETTI, PRC92, 025202 (2015)

A long standing problem of three quarks QMs in the strange sector is that of $\Lambda^*(1405)$, since its experimental mass is not reproduced with a reasonable accuracy within this kind of models. Here, the mass of this resonance is well reproduced in terms of a quark-diquark picture of baryons.

$\Lambda(1116)$ and $\Lambda^*(1520)$ are described as bound states of a scalar diquark $[n, n]$ and a quark s, where the quark-diquark system is in S or P-wave, respectively. This is in accordance with the observations of Refs. [29, 30] on Λ's fragmentation functions, that the two resonances can be described as $[n, n] - s$ systems. See Table VII.

Strong decays of Baryons and Missing resonances

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different CQMs for bayons

	Kin. Energy	SU(6) inv	SU(6) viol	date
Isgur-Karl	non rel	h.o. + shift	OGE	1978-9
Capstick-Isgur	rel	string + coul-like	OGE	1986
U(7) B.I.L.	rel M^2	vibr+L	Guersey-R	1994
Hyp. O(6)	non rel/rel	hyp.coul+linear	OGE	1995
Glozman Riska	non rel/rel**Plessas**	h.o./linear	GBE	1996
Bonn	rel	linear 3-body	instanton	2001

$U(7)$ Model Ann. Phys. **284**, 89 (2000)

- In the $U(7)$ algebraic model the baryon spectrum is computed through algebraic methods, introduced in the 60's by Gell-Mann, Ne'eman and Okubo (flavor and spin part). In the U(7) model, such methods are also used to describe the spatial part.
- The full algebraic structure is obtained by combining the symmetry of the spatial part, $U(7)$, with that of the internal spin-flavor-color part $SU_{\mathrm{sf}}(6) \otimes SU_{\mathrm{c}}(3)$

$$U(7) \otimes SU_{\mathrm{sf}}(6) \otimes SU_{\mathrm{c}}(3) \ .$$

- The baryon mass formula is written as the sum of three terms

$$\hat{M}^2 = M_0^2 + \hat{M}^2_{\mathrm{space}} + \hat{M}^2_{\mathrm{sf}} \ ,$$

where $\hat{M}^2_{\mathrm{space}}$ is a function of the spatial degrees of freedom and $\hat{M}^2_{\mathrm{sf}}$ depends on the internal ones. The energy spectrum, corresponding to the spatial degrees of freedom, is given by:

$$\hat{M}^2_{\mathrm{space}} = \hat{M}^2_{\mathrm{vib}} + \hat{M}^2_{\mathrm{rot}} \ .$$

Since the space-spin-flavor wave function is symmetric under permutation group S_3 of the three identical constituents, the permutation symmetry of the spatial wave function has to be the same as that of the spin-flavor part. Thus, the spatial part of the mass operator $\hat{M}^2_{\mathrm{space}}$ has to be invariant under the S_3 permutation symmetry.

- The mass formula

$$\hat{M}^2 = M_0^2 + \kappa_1 \, v_1 + \kappa_2 \, v_2 + \alpha L + M^2_{\mathrm{GR}} \ ,$$

N^* Spectra in $U(7)$ Model Ann. Phys. **284**, 89 (2000)

Mass spectrum of nonstrange baryon resonances in the oblate top model. The masses are given in MeV.

Baryon $L_{2I,2J}$	Status	Mass	State	(v_1, v_2)	M_{calc}
$N(939)P_{11}$	****	939	$^{2}8_{1/2}[56, 0^{+}]$	(0,0)	939
$N(1440)P_{11}$	****	1430-1470	$^{2}8_{1/2}[56, 0^{+}]$	(1,0)	1444
$N(1520)D_{13}$	****	1515-1530	$^{2}8_{3/2}[70, 1^{-}]$	(0,0)	1563
$N(1535)S_{11}$	****	1520-1555	$^{2}8_{1/2}[70, 1^{-}]$	(0,0)	1563
$N(1650)S_{11}$	****	1640-1680	$^{4}8_{1/2}[70, 1^{-}]$	(0,0)	1683
$N(1675)D_{15}$	****	1670-1685	$^{4}8_{5/2}[70, 1^{-}]$	(0,0)	1683
$N(1680)F_{15}$	****	1675-1690	$^{2}8_{5/2}[56, 2^{+}]$	(0,0)	1737
$N(1700)D_{13}$	***	1650-1750	$^{4}8_{3/2}[70, 1^{-}]$	(0,0)	1683
$N(1710)P_{11}$	***	1680-1740	$^{2}8_{1/2}[70, 0^{+}]$	(0,1)	1683
missing			$^{2}8_{1/2}[20, 1^{+}]$	(0,0)	1713
missing			$^{2}8_{3/2}[20, 1^{+}]$	(0,0)	1713
$N(1720)P_{13}$	****	1650-1750	$^{2}8_{3/2}[56, 2^{+}]$	(0,0)	1737
misssin			$^{2}8_{3/2}[70, 2^{-}]$	(0,0)	1874
misssin			$^{2}8_{5/2}[70, 2^{-}]$	(0,0)	1874
misssin			$^{2}8_{5/2}[70, 2^{+}]$	(0,0)	1874
$N(1860)F_{15}$	**	1820-1960	$^{4}8_{5/2}[70, 2^{+}]$	(0,0)	1975
$N(1875)D_{13}$	***	1820-1920	$^{4}8_{3/2}[70, 2^{-}]$	(0,0)	1975
$N(1880)P_{13}$	**	1835-1905	$^{4}8_{3/2}[70, 2^{+}]$	(0,0)	1975
$N(1895)S_{11}$	**	1880-1910	$^{4}8_{1/2}[70, 2^{-}]$	(0,0)	1975
$N(1900)P_{13}$	***	1875-1935	$^{2}8_{3/2}[70, 2^{+}]$	(0,0)	1874

The Hypercentral Model (hQM) PL. **B364**, 231 (1995)

In the hQM, the Jacobi coordinates $\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r}_1 - \vec{r}_2)$ and $\vec{\lambda} = \frac{1}{\sqrt{6}}(\vec{r}_1 + \vec{r}_2 - 2\vec{r}_3)$, which constitute the usual choice in QM calculations, are substituted with the hyperspherical coordinates. These are the angles $\Omega_\rho = (\theta_\rho, \phi_\rho)$ and $\Omega_\lambda = (\theta_\lambda, \phi_\lambda)$, the hyperradius, x, and the hyperangle, ξ, defined as

$$x = \sqrt{\vec{\rho}^2 + \vec{\lambda}^2} \,, \qquad \xi = \arctan \frac{\rho}{\lambda} \,.$$

the hQM has the assumption that the quark interaction only depends on the hyperradius :

$$V_{3q}(\vec{\rho}, \vec{\lambda}) = V(x)$$

With the form

$$V(x) = -\frac{\tau}{x} + \alpha x$$

where τ and α are free parameters. Thus, ψ_{space}, is factorized as

$$\psi_{space} = \psi_{3q}(\vec{\rho}, \vec{\lambda}) = \psi_{\gamma\nu}(x) Y_{[\gamma] l_\rho l_\lambda}(\Omega_\rho, \Omega_\lambda, \xi) \,,$$

where the hyperradial wave function, $\psi_{\gamma\nu}(x)$, is labeled by the grand angular quantum number γ and the number of nodes ν. The dynamics is contained in $\psi_{\gamma\nu}(x)$, which is a solution of the hyperradial equation

$$[\frac{d^2}{dx^2} + \frac{5}{x}\frac{d}{dx} - \frac{\gamma(\gamma+4)}{x^2}]\psi_{\gamma\nu}(x) = -2m\,[E - V_{3q}(x)]\;\psi_{\gamma\nu}(x) \,.$$

The complete hCQM hamiltonian is then

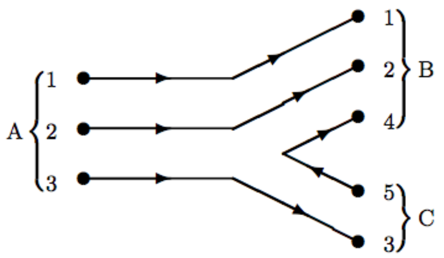
$$H_{hCQM} = 3m + \frac{\vec{p}_\rho^{\,2}}{2m} + \frac{\vec{p}_\lambda^{\,2}}{2m} - \frac{\tau}{x} + \alpha x + H_{hyp}.$$

The baryon spectra in the hQM P. L. **B364**, 231 (1995)

Mass spectrum of N and Δ resonances within the hQM, compared with the existing experimental data.

Baryon $L_{2I,2J}$	Status	Mass (MeV)	State	M_{hQM} (MeV)
$N(939)P_{11}$	****	939	$^{2}8_{1/2}[56,0_1^+]$	938
$N(1440)P_{11}$	****	1420-1470	$^{2}8_{1/2}[56,0_2^+]$	1550
$N(1520)D_{13}$	****	1515-1525	$^{2}8_{3/2}[70,1_1^-]$	1525
$N(1535)S_{11}$	****	1525-1545	$^{2}8_{1/2}[70,1_1^-]$	1507
$N(1650)S_{11}$	****	1645-1670	$^{2}8_{1/2}[70,1_2^-]$	1574
$N(1675)D_{15}$	****	1670-1680	$^{4}8_{5/2}[70,1_1^-]$	1579
$N(1680)F_{15}$	****	1680-1690	$^{2}8_{5/2}[56,2_1^+]$	1798
$N(1700)D_{13}$	***	1650-1750	$^{2}8_{3/2}[70,1_2^-]$	1606
$N(1710)P_{11}$	***	1680-1740	$^{2}8_{1/2}[70,0_1^+]$	1808
$N(1720)P_{13}$	****	1700-1750	$^{2}8_{3/2}[56,2_1^+]$	1797
missing			$^{4}8_{3/2}[70,2_1^+]$	1835
missing			$^{2}8_{1/2}[20,1_1^+]$	1836
missing			$^{2}8_{3/2}[20,1_1^+]$	1836
$N(1860)F_{15}$	**	1820-1960	$^{4}8_{5/2}[70,2_1^+]$	1844
$N(1875)D_{13}$	***	1820-1920	$^{4}8_{3/2}[70,1_1^-]$	1899
$N(1880)P_{11}$	**	1835-1905	$^{4}8_{1/2}[70,2_1^+]$	1839
$N(1895)S_{11}$	**	1880-1910	$^{4}8_{1/2}[70,1_1^-]$	1887
$N(1900)P_{13}$	***	1875-1935	$^{2}8_{3/2}[70,2_1^+]$	1853
missing			$^{4}8_{1/2}[70,1_2^-]$	1937
$N(1990)F_{17}$	**	1995-2125	$^{4}8_{7/2}[70,2_1^+]$	1840

Strong Decays of baryons, $3P_0$ mechanism arXiv:1506.07469



The $^3P_0$ pair-creation model of hadron vertices; the $q\bar{q}$ pair (45) is created in a $^3P_0$ flavor-color singlet. A is the initial state baryon, B and C are the final baryon and meson states, respectively.

The $^3P_0$ operator

$$T^\dagger = -3\gamma \sum_{i,j} \int d\vec{p}_i d\vec{p}_j \delta(\vec{p}_i + \vec{p}_j) C_{ij} F_{ij} V(p_i - p_j)^2 \left[\chi_{ij} \times \mathcal{Y}_1(\vec{p}_i - \vec{p}_j)\right]_0^{(0)} b_i^\dagger(\vec{p}_i) d_j^\dagger(\vec{p}_j)$$

$$\gamma_0 \to \gamma_0^{\text{eff}} = \frac{m_n}{m_i} \gamma_0 .$$

$$\Gamma_{A\to BC} = \Phi_{A\to BC}(q_0) \sum_{\ell} \left| \langle BCq_0\, \ell J | \, T^\dagger \, |A\rangle \right|^2$$

$$\Phi_{A\to BC}(q_0) = 2\pi q_0 \frac{E_b(q_0)E_c(q_0)}{M_a} \ , \qquad (21)$$

depending on q_0 and on the energies of the two intermediate-state hadrons, $E_b = \sqrt{M_b^2 + q_0^2}$ and $E_c = \sqrt{M_c^2 + q_0^2}$. The third possibility is to use an effective phase space factor [3, 15],

$$\Phi_{A\to BC}(q_0) = 2\pi q_0 \frac{\tilde{M}_b \tilde{M}_c}{M_a} \ , \qquad (22)$$

where $\tilde{M}_b$ and $\tilde{M}_c$ are the effective baryon and meson masses, respectively, evaluated by means of a spin-independent interaction (see Table I). According to Ref. [15], this is valid in the weak-binding limit, where ρ and π are degenerate and $\tilde{m}_\pi = 5.1 m_\pi$.

In the case of heavy baryons and mesons, whose internal dynamics is almost non-relativistic and the hyperfine interactions are relatively small, the three types of phase space factors provide almost the same results.

$U(7)$ Model Results, arXiv:1506.07469

3* and 4* states

TABLE III: Strong decay widths of three- and four-star nucleon resonances (in MeV), calculated with the U(7) Model of II A and Refs. [39, 40], in combination with the relativistic phase space factor (RPSF) of Eq. (21) and the values of the m parameters of Table II (second column), or the effective phase space factor (EPSF) of Eq. (22) and the values of the m parameters of Table II (third column). The experimental values are taken from Ref. [1]. Decay channels labeled by – are b threshold. The symbols (S) and (D) stand for S- and D-wave decays, respectively.

Resonance	Status	M [MeV]	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$N\rho$	$N\omega$	
$N(1440)P_{11}$	****	1430-1470	$110-338$	$0-5$			$22-101$			Exp.
$^28_{1/2}[56,0_2^+]$		1444	85	–	–	–	13	–	–	RPSF
$^28_{1/2}[56,0_2^+]$		1444	108	–			22			EPSF
$N(1520)D_{13}$	****	1515-1530	102	0			342			Exp.
$^28_{3/2}[70,1_1^-]$		1563	134	0	–	–	207	–	–	RPSF
$^28_{3/2}[70,1_1^-]$		1563	102	0			342			EPSF
$N(1535)S_{11}$	****	1520-1555	$44-96$	$40-91$			<2			Exp.
$^28_{1/2}[70,1_1^-]$		1563	63	75	–	–	16	–	–	RPSF
$^28_{1/2}[70,1_1^-]$		1563	106	86			14			EPSF
$N(1650)S_{11}$	****	1640-1680	$60-162$	$6-27$		$4-20$	$0-45$			Exp.
$^48_{1/2}[70,1_1^-]$		1683	41	72	–	0	18	–	–	RPSF
$^48_{1/2}[70,1_1^-]$		1683	71	83			15			EPSF
$N(1675)D_{15}$	****	1670-1685	$46-74$	$0-2$		<2	$65-99$			Exp.
$^48_{5/2}[70,1_1^-]$		1683	47	11	–	0	108	–	–	RPSF
$^48_{5/2}[70,1_1^-]$		1683	29	7			79			EPSF
$N(1680)F_{15}$	****	1675-1690	$78-98$	$0-1$			$6-21$			Exp.
$^28_{5/2}[56,2_1^+]$		1737	121	1	–	0	100	–	–	RPSF
$^28_{5/2}[56,2_1^+]$		1737	63	0			99			EPSF
$N(1700)D_{13}$	***	1650-1750	$7-43$	$0-3$		<8	$10-225$ (S) <50 (D)			Exp.
$^48_{3/2}[70,1_1^-]$		1683	9	3	–	0	561	–	–	RPSF
$^48_{3/2}[70,1_1^-]$		1683	5	2			657			EPSF
$N(1710)P_{11}$	***	1680-1740	$3-50$	$5-75$		$3-63$	$8-100$	$3-63$		Exp.
$^28_{1/2}[70,0_1^+]$		1683	5	9	0	3	56	–	–	RPSF
$^28_{1/2}[70,0_1^+]$		1683	11	9			58			EPSF
$N(1720)P_{13}$	****	1650-1750	$12-56$	$5-20$		$2-60$	$90-360$	$105-340$		Exp.
$^28_{3/2}[56,2_1^+]$		1737	111	7	0	14	36	5	0	RPSF
$^28_{3/2}[56,2_1^+]$		1737	123	7			28			EPSF
$N(1875)D_{13}$	***	1820-1920	$3-70$	$0-22$	$0-4$		$48-192$ (S) $11-86$ (D)	$0-38$	$22-90$	Exp. Exp.
$^48_{3/2}[70,2_1^-]$		1975	0	0	0	0	0	0	0	RPSF
$^48_{3/2}[70,2_1^-]$		1975	0	0			0			EPSF
$N(1900)P_{13}$	***	1875-1935	$20-37$	$24-44$	$6-26$	$0-37$			$75-120$	Exp.
$^28_{3/2}[70,2_1^+]$		1874	11	12	1	13	63	64	24	RPSF
$^28_{3/2}[70,2_1^+]$		1874	17	11			33			EPSF

$U(7)$ Model Results, arXiv:1506.07469

3* and 4* states

TABLE IV: As Table III, but for Δ resonances. The symbols (S), (P), (D) and (F) stand for S-, P-, D- and F-wave decays, respectively.

Resonance	Status	M [MeV]	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$	
$\Delta(1232)P_{33}$	****	1230-1234	$114-120$						Exp.
$^4 10_{3/2}[56,0_1^+]$		1246	71	–	–	–	–	–	RPSF
$^4 10_{3/2}[56,0_1^+]$		1246	115		–	–			EPSF
$\Delta(1600)P_{33}$	***	1550-1700	$22-105$		$88-294$			< 88	Exp.
$^4 10_{3/2}[56,0_2^+]$		1660	17	–	65	–	–	–	RPSF
$^4 10_{3/2}[56,0_2^+]$		1660	24		74	–			EPSF
$\Delta(1620)S_{31}$	****	1615-1675	$26-45$		$39-90$			$9-38$	Exp.
$^2 10_{1/2}[70,1_1^-]$		1649	5	–	76	–	–	–	RPSF
$^2 10_{1/2}[70,1_1^-]$		1649	10		61	–			EPSF
$\Delta(1700)D_{33}$	****	1670-1770	$20-80$		$50-200$ (S) $10-60$ (D)	$6-28$		$48-165$	Exp.
$^2 10_{3/2}[70,1_1^-]$		1649	46	–	311	–	–	–	RPSF
$^2 10_{3/2}[70,1_1^-]$		1649	27		343	–			EPSF
$\Delta(1905)F_{35}$	****	1855-1910	$24-60$		< 100			> 162	Exp.
$^4 10_{5/2}[56,2_1^+]$		1921	31	1	188	19	0	99	RPSF
$^4 10_{5/2}[56,2_1^+]$		1921	14		139	14			EPSF
$\Delta(1910)P_{31}$	****	1860-1910	$33-102$	$9-48$	$70-299$				Exp.
$^4 10_{1/2}[56,2_1^+]$		1921	26	38	32	4	–	64	RPSF
$^4 10_{1/2}[56,2_1^+]$		1921	39		27	3			EPSF
$\Delta(1920)P_{33}$	***	1900-1970	$9-60$	$3-7$	$18-102$ (P) $45-195$ (F)	$13-69$		0	Exp.
$^4 10_{3/2}[56,2_1^+]$		1921	7	23	132	22	5	105	RPSF
$^4 10_{3/2}[56,2_1^+]$		1921	14		96	15			EPSF
$\Delta(1930)D_{35}$	***	1920-1970	$11-75$						Exp.
$^2 10_{5/2}[70,2_1^-]$		1946	0	0	0	0	0	0	RPSF
$^2 10_{5/2}[70,2_1^-]$		1946	0		0	0			EPSF
$\Delta(1950)F_{37}$	****	1940-1960	$82-151$	$1-2$	$47-101$			< 34	Exp.
$^4 10_{7/2}[56,2_1^+]$		1921	172	5	92	1	0	22	RPSF
$^4 10_{7/2}[56,2_1^+]$		1921	72		40	1			EPSF

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3* and 4* states

TABLE V: As Table III, but for Σ and Σ^* resonances.

Baryon	Status	M [MeV]	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$N\overline{K}^*$	$\Sigma\rho$	$\Lambda\rho$	$\Sigma\omega$	
$\Sigma(1660)P_{11}$	***	1630-1690	$4-60$	seen	seen									Exp.
$^2 8_{1/2}[56,0_2^+]$		1604	3	38	14	–	–	–	7	–	–	–	–	RPSF
$\Sigma(1670)D_{13}$	****	1665-1685	$3-10$	$12-48$	$2-12$									Exp.
$^4 8_{3/2}[70,1_1^-]$		1711	5	78	8	–	–	–	36	–	–	–	–	RPSF
$\Sigma(1750)S_{11}$	***	1730-1800	$6-64$	< 13	seen	$9-88$								Exp.
$^4 8_{1/2}[70,1_1^-]$		1711	3	109	3	28	–	–	9	–	–	–	–	RPSF
$\Sigma(1775)D_{15}$	****	1770-1780	$39-58$	$2-7$	$15-27$				$8-16$					Exp.
$^4 8_{5/2}[70,1_1^-]$		1822	101	17	38	0	–	4	11	–	–	–	–	RPSF
$\Sigma(1915)F_{15}$	****	1900-1935	$4-24$	seen	seen				< 8					Exp.
$^2 8_{5/2}[56,2_1^+]$		1872	6	58	33	2	1	96	23	6	–	2	–	RPSF
$\Sigma(1940)D_{13}$	***	1900-1950	< 60	seen	seen			seen	seen	seen				Exp.
$^2 8_{3/2}[56,1_1^-]$		1974	0	0	0	0	0	0	0	0	–	0	–	RPSF
$\Sigma^*(1385)P_{13}$	****	1383-1385		$30-32$	$4-5$									Exp.
$^4 10_{3/2}[56,0_1^+]$		1382	–	3	27	–	–	–	–	–	–	–	–	RPSF
$\Sigma^*(2030)F_{17}$	****	2025-2040	$26-46$	$8-20$	$26-46$		< 4	$15-40$	$8-30$					Exp.
$^4 10_{7/2}[56,2_1^+]$		2012	54	37	75	271	1	30	37	7	0	4	0	RPSF

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TABLE VI: As Table III, but for Λ and Λ^* resonances.

Baryon	Status	M [MeV]	$N\overline{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$\Sigma^*\pi$	$N\overline{K}^*$	$\Sigma\rho$	$\Lambda\omega$	
$\Lambda(1600)P_{01}$	***	1560-1700	$8-75$	$5-150$							Exp.
$^2 8_{1/2}[56, 0_2^+]$		1577	79	40	–	–	19	–	–	–	RPSF
$\Lambda(1670)S_{01}$	****	1660-1680	$5-15$	$6-28$	$3-13$						Exp.
$^2 8_{1/2}[70, 1_1^-]$		1686	217	33	9	–	7	–	–	–	RPSF
$\Lambda(1690)D_{03}$	****	1685-1690	$10-21$	$10-28$							Exp.
$^2 8_{3/2}[70, 1_1^-]$		1686	150	16	0	–	168	–	–	–	RPSF
$\Lambda(1800)S_{01}$	***	1720-1850	$50-160$	seen			seen				Exp.
$^4 8_{1/2}[70, 1_1^-]$		1799	0	67	85	–	13	–	–	–	RPSF
$\Lambda(1810)P_{01}$	***	1750-1850	$10-125$	$5-100$			seen				Exp.
$^2 8_{1/2}[70, 0_1^+]$		1799	16	4	2	–	40	–	–	–	RPSF
$\Lambda(1820)F_{05}$	****	1815-1825	$39-59$	$6-13$			$4-9$				Exp.
$^2 8_{5/2}[56, 2_1^+]$		1849	78	31	1	0	73	–	–	–	RPSF
$\Lambda(1830)D_{05}$	****	1810-1830	$2-11$	$21-83$			> 9				Exp.
$^4 8_{5/2}[70, 1_1^-]$		1799	0	99	9	0	82	–	–	–	RPSF
$\Lambda(1890)P_{03}$	****	1850-1910	$12-70$	$2-20$			seen				Exp.
$^2 8_{3/2}[56, 2_1^+]$		1849	96	69	31	2	30	28	–	–	RPSF
$\Lambda(2110)F_{05}$	****	2090-2140	$8-63$	$15-100$			seen				Exp.
$^4 8_{5/2}[70, 2_1^+]$		2074	0	14	3	1	136	0	38	16	RPSF
$\Lambda^*(1405)S_{01}$	****	1402-1410		$48-52$							Exp.
$^2 1_{1/2}[70, 1_1^-]$		1641	–	230	–	–	–	–	–	–	RPSF
$\Lambda^*(1520)D_{03}$	****	1518-1520	$6-8$	$6-7$			1				Exp.
$^2 1_{3/2}[70, 1_1^-]$		1641	10	17	–	–	–	–	–	–	RPSF

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3* and 4* states

TABLE VII: As Table III, but for Ξ and Ξ^*resonances.

Baryon	Status	M [MeV]	$\Sigma\overline{K}$	$\Lambda\overline{K}$	$\Xi\pi$	$\Xi^*\pi$	
$\Xi(1690)S_{11}$	***	1680-1700					Exp.
$^2 8_{1/2}[70, 1_1^-]$		1828	58	85	14	0	RPSF
$\Xi(1820)D_{13}$	***	1818-1828	$2-18$	$3-12$	$0-8$	$2-18$	Exp.
$^2 8_{3/2}[70, 1_1^-]$		1828	38	26	6	55	RPSF
$\Xi^*(1530)P_{13}$	****	1531-1532			$9-10$		Exp.
$^4 10_{3/2}[56, 0_1^+]$		1524	–	–	11	–	RPSF

TABLE VIII: Strong decay widths of missing nucleon resonances (in MeV), calculated with the U(7) Model of Sec. II A and Refs. [39, 40], in combination with the relativistic phase space factor of Eq. (21) and the values of the model parameters of Table II (second column). Tentative assignments of one and two star resonances are labeled by ‡.

N	Mass	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$\Sigma^* K$	$N\rho$	$N\omega$	ΣK^*	ΛK^*	$\Delta\rho$
$^2 8_J[20, 1_1^+]$	1713	0	0	0	0	0	–	–	–	–	–	–
$^4 8_{3/2}[70, 0_1^+]$	1796	0	3	5	0	65	–	7	7	–	–	–
$^2 8_{5/2}[70, 2_1^+]$	1874 ‡	106	10	0	3	79	–	161	8	–	–	–
$^2 8_J[70, 2_1^-]$	1874	0	0	0	0	0	–	0	0	–	–	–
$^4 8_{1/2}[70, 2_1^+]$	1975 ‡	1	8	23	0	19	1	9	9	–	–	–
$^4 8_{3/2}[70, 2_1^+]$	1975 ‡	0	4	11	0	109	5	14	14	–	–	–
$^4 8_{5/2}[70, 2_1^+]$	1975 ‡	6	3	1	0	176	6	16	16	–	–	–
$^4 8_{7/2}[70, 2_1^+]$	1975 ‡	25	13	4	0	99	0	5	4	–	–	–
$^4 8_J[70, 2_1^-]$	1975 ‡	0	0	0	0	0	0	0	0	–	–	–
$^2 8_{1/2}[56, 1_1^-]$	2094	5	1	1	5	3	2	48	6	2	2	14
$^2 8_{3/2}[56, 1_1^-]$	2094 ‡	27	0	0	1	23	1	53	11	0	2	13
$^2 8_{1/2}[70, 1_2^-]$	1829 ‡	42	7	0	1	38	–	0	0	–	–	–
$^4 8_{1/2}[70, 1_2^-]$	1933	8	12	3	0	0	0	0	0	–	–	–
$^4 8_{3/2}[70, 1_2^-]$	1933	0	0	3	0	0	0	0	0	–	–	–
$^4 8_{5/2}[70, 1_2^-]$	1933	0	2	5	0	1	0	0	0	–	–	–

$U(7)$ Model Results, arXiv:1506.07469 Missing resonances

TABLE XII: As Table VIII, but for missing Ξ (top) and Ξ^* (bottom) resonances.

Ξ	Mass	$\Sigma\overline{K}$	$\Lambda\overline{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\overline{K}$	$\Xi^*\pi$	$\Lambda\overline{K}^*$
$^2 8_{1/2}[70,0_1^+]$	1932	36	6	1	11	7	13	–
$^4 8_{1/2}[70,1_1^-]$	1932	43	20	69	0	0	4	–
$^4 8_{3/2}[70,1_1^-]$	1932	4	7	22	0	216	152	–
$^4 8_{5/2}[70,1_1^-]$	1932	23	39	132	0	2	19	–
$^2 8_J[20,1_1^+]$	1957	0	0	0	0	0	0	–
$^2 8_{3/2}[56,2_1^+]$	1979	198	7	6	47	4	7	–
$^2 8_{5/2}[56,2_1^+]$	1979	59	5	4	1	20	27	–
$^4 8_{3/2}[70,0_1^+]$	2031	2	1	3	0	24	19	2
$^2 8_{1/2}[56,0_2^+]$	1727	26	4	3	–	–	2	–
$^2 10_{1/2}[70,1_1^-]$	1869	17	10	7	7	–	7	–
$^2 10_{3/2}[70,1_1^-]$	1869	5	10	9	0	–	61	–
$^2 10_{1/2}[70,0_1^+]$	1971	2	1	1	2	51	14	–
$^4 10_{3/2}[56,0_2^+]$	1878	19	16	13	1	–	12	–

TABLE XIII: As Table VIII, but for missing Ω resonances.

Ω	Mass	$\Xi\overline{K}$	$\Xi^*\overline{K}$
$^2 10_{1/2}[70,1_1^-]$	1989	68	–
$^2 10_{3/2}[70,1_1^-]$	1989	20	–
$^2 10_{1/2}[70,0_1^+]$	2085	8	32
$^4 10_{3/2}[56,0_2^+]$	1998	79	–

U(7) Sigma missing states

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ
$^4 8_{1/2}[70, 1_1^-]$	1822	24	11	6	20	10	5	4	–	
$^4 8_{3/2}[70, 1_1^-]$	1822	22	4	8	0	0	602	98	–	
$^2 8_{1/2}[70, 0_1^+]$	1822 ‡	1	20	1	1	0	33	9	–	
$^2 8_{1/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[56, 2_1^+]$	1872	4	62	19	23	12	17	6	–	
$^4 8_{3/2}[70, 0_1^+]$	1926	0	0	0	5	1	65	12	–	
$^2 8_{3/2}[70, 2_1^+]$	1999	1	31	1	7	14	28	8	1	
$^2 8_{5/2}[70, 2_1^+]$	1999	4	76	6	1	1	60	13	4	
$^2 8_{5/2}[70, 2_1^-]$	1999	0	0	0	0	0	0	0	0	
$^4 8_{1/2}[70, 2_1^+]$	2095	4	2	1	3	4	18	4	4	
$^4 8_{3/2}[70, 2_1^+]$	2095	2	1	1	2	2	84	18	13	
$^4 8_{5/2}[70, 2_1^+]$	2095 ‡	15	3	5	1	0	128	29	18	
$^4 8_{7/2}[70, 2_1^+]$	2095	69	13	24	2	1	54	15	1	

U(7) Sigma missing states II

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ^*
$^4 8_{1/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{3/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{5/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{7/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^2 8_{1/2}[70, 1_2^-]$	1957 ‡	0	0	0	0	0	0	0	0	-
$^2 8_{3/2}[70, 1_2^-]$	1957	0	0	0	0	0	0	0	0	-
$^4 8_{1/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-
$^4 8_{3/2}[70, 1_2^-]$	2055	0	0	0	0	0	1	0	0	-
$^4 8_{5/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-

$U(7)$ Model Results, arXiv:1506.07469 Missing resonances

TABLE XII: As Table VIII, but for missing Ξ (top) and Ξ^* (bottom) resonances.

Ξ	Mass	$\Sigma\overline{K}$	$\Lambda\overline{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\overline{K}$	$\Xi^*\pi$	$\Lambda\overline{K}^*$
$^2 8_{1/2}[70, 0_1^+]$	1932	36	6	1	11	7	13	–
$^4 8_{1/2}[70, 1_1^-]$	1932	43	20	69	0	0	4	–
$^4 8_{3/2}[70, 1_1^-]$	1932	4	7	22	0	216	152	–
$^4 8_{5/2}[70, 1_1^-]$	1932	23	39	132	0	2	19	–
$^2 8_J[20, 1_1^+]$	1957	0	0	0	0	0	0	–
$^2 8_{3/2}[56, 2_1^+]$	1979	198	7	6	47	4	7	–
$^2 8_{5/2}[56, 2_1^+]$	1979	59	5	4	1	20	27	–
$^4 8_{3/2}[70, 0_1^+]$	2031	2	1	3	0	24	19	2
$^2 8_{1/2}[56, 0_2^+]$	1727	26	4	3	–	–	2	–
$^2 10_{1/2}[70, 1_1^-]$	1869	17	10	7	7	–	7	–
$^2 10_{3/2}[70, 1_1^-]$	1869	5	10	9	0	–	61	–
$^2 10_{1/2}[70, 0_1^+]$	1971	2	1	1	2	51	14	–
$^4 10_{3/2}[56, 0_2^+]$	1878	19	16	13	1	–	12	–

TABLE XIII: As Table VIII, but for missing Ω resonances.

Ω	Mass	$\Xi\overline{K}$	$\Xi^*\overline{K}$
$^2 10_{1/2}[70, 1_1^-]$	1989	68	–
$^2 10_{3/2}[70, 1_1^-]$	1989	20	–
$^2 10_{1/2}[70, 0_1^+]$	2085	8	32
$^4 10_{3/2}[56, 0_2^+]$	1998	79	–

U(7) Sigma missing states

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ
$^4 8_{1/2}[70, 1_1^-]$	1822	24	11	6	20	10	5	4	–	
$^4 8_{3/2}[70, 1_1^-]$	1822	22	4	8	0	0	602	98	–	
$^2 8_{1/2}[70, 0_1^+]$	1822 ‡	1	20	1	1	0	33	9	–	
$^2 8_{1/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[56, 2_1^+]$	1872	4	62	19	23	12	17	6	–	
$^4 8_{3/2}[70, 0_1^+]$	1926	0	0	0	5	1	65	12	–	
$^2 8_{3/2}[70, 2_1^+]$	1999	1	31	1	7	14	28	8	1	
$^2 8_{5/2}[70, 2_1^+]$	1999	4	76	6	1	1	60	13	4	
$^2 8_{5/2}[70, 2_1^-]$	1999	0	0	0	0	0	0	0	0	
$^4 8_{1/2}[70, 2_1^+]$	2095	4	2	1	3	4	18	4	4	
$^4 8_{3/2}[70, 2_1^+]$	2095	2	1	1	2	2	84	18	13	
$^4 8_{5/2}[70, 2_1^+]$	2095 ‡	15	3	5	1	0	128	29	18	
$^4 8_{7/2}[70, 2_1^+]$	2095	69	13	24	2	1	54	15	1	

U(7) Sigma missing states II

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ^*
$^4 8_{1/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{3/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{5/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{7/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^2 8_{1/2}[70, 1_2^-]$	1957 ‡	0	0	0	0	0	0	0	0	-
$^2 8_{3/2}[70, 1_2^-]$	1957	0	0	0	0	0	0	0	0	-
$^4 8_{1/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-
$^4 8_{3/2}[70, 1_2^-]$	2055	0	0	0	0	0	1	0	0	-
$^4 8_{5/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-

$U(7)$ Model Results, arXiv:1506.07469 Missing resonances

TABLE IX: As Table VIII, but for missing Δ resonances.

Δ	Mass	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$
${}^{2}10_{1/2}[70, 0_1^+]$	1764 ‡	0	1	70	–	–	23
${}^{2}10_{3/2}[70, 2_1^-]$	1946	0	0	0	0	0	0
${}^{2}10_{3/2}[70, 2_1^+]$	1947	1	3	106	5	1	80
${}^{2}10_{5/2}[70, 2_1^+]$	1947 ‡	18	1	107	18	4	32
${}^{2}10_{1/2}[70, 1_2^-]$	1904 ‡	0	0	0	0	0	0
${}^{2}10_{3/2}[70, 1_2^-]$	1904	0	0	0	0	0	0

$U(7)$ Model Results, arXiv:1506.07469 Missing resonances

TABLE XII: As Table VIII, but for missing Ξ (top) and Ξ^* (bottom) resonances.

Ξ	Mass	$\Sigma\overline{K}$	$\Lambda\overline{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\overline{K}$	$\Xi^*\pi$	$\Lambda\overline{K}^*$
$^{2}8_{1/2}[70,0_1^+]$	1932	36	6	1	11	7	13	–
$^{4}8_{1/2}[70,1_1^-]$	1932	43	20	69	0	0	4	–
$^{4}8_{3/2}[70,1_1^-]$	1932	4	7	22	0	216	152	–
$^{4}8_{5/2}[70,1_1^-]$	1932	23	39	132	0	2	19	–
$^{2}8_{J}[20,1_1^+]$	1957	0	0	0	0	0	0	–
$^{2}8_{3/2}[56,2_1^+]$	1979	198	7	6	47	4	7	–
$^{2}8_{5/2}[56,2_1^+]$	1979	59	5	4	1	20	27	–
$^{4}8_{3/2}[70,0_1^+]$	2031	2	1	3	0	24	19	2
$^{2}8_{1/2}[56,0_2^+]$	1727	26	4	3	–	–	2	–
$^{2}10_{1/2}[70,1_1^-]$	1869	17	10	7	7	–	7	–
$^{2}10_{3/2}[70,1_1^-]$	1869	5	10	9	0	–	61	–
$^{2}10_{1/2}[70,0_1^+]$	1971	2	1	1	2	51	14	–
$^{4}10_{3/2}[56,0_2^+]$	1878	19	16	13	1	–	12	–

TABLE XIII: As Table VIII, but for missing Ω resonances.

Ω	Mass	$\Xi\overline{K}$	$\Xi^*\overline{K}$
$^{2}10_{1/2}[70,1_1^-]$	1989	68	–
$^{2}10_{3/2}[70,1_1^-]$	1989	20	–
$^{2}10_{1/2}[70,0_1^+]$	2085	8	32
$^{4}10_{3/2}[56,0_2^+]$	1998	79	–

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ
$^4 8_{1/2}[70, 1_1^-]$	1822	24	11	6	20	10	5	4	–	
$^4 8_{3/2}[70, 1_1^-]$	1822	22	4	8	0	0	602	98	–	
$^2 8_{1/2}[70, 0_1^+]$	1822 ‡	1	20	1	1	0	33	9	–	
$^2 8_{1/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[20, 1_1^+]$	1849 ‡	0	0	0	0	0	0	0	–	
$^2 8_{3/2}[56, 2_1^+]$	1872	4	62	19	23	12	17	6	–	
$^4 8_{3/2}[70, 0_1^+]$	1926	0	0	0	5	1	65	12	–	
$^2 8_{3/2}[70, 2_1^+]$	1999	1	31	1	7	14	28	8	1	
$^2 8_{5/2}[70, 2_1^+]$	1999	4	76	6	1	1	60	13	4	
$^2 8_{5/2}[70, 2_1^-]$	1999	0	0	0	0	0	0	0	0	
$^4 8_{1/2}[70, 2_1^+]$	2095	4	2	1	3	4	18	4	4	
$^4 8_{3/2}[70, 2_1^+]$	2095	2	1	1	2	2	84	18	13	
$^4 8_{5/2}[70, 2_1^+]$	2095 ‡	15	3	5	1	0	128	29	18	
$^4 8_{7/2}[70, 2_1^+]$	2095	69	13	24	2	1	54	15	1	

U(7) Sigma missing states II

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	Ξ^*
$^4 8_{1/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{3/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{5/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^4 8_{7/2}[70, 2_1^-]$	2095	0	0	0	0	0	0	0	0	(
$^2 8_{1/2}[70, 1_2^-]$	1957 ‡	0	0	0	0	0	0	0	0	-
$^2 8_{3/2}[70, 1_2^-]$	1957	0	0	0	0	0	0	0	0	-
$^4 8_{1/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-
$^4 8_{3/2}[70, 1_2^-]$	2055	0	0	0	0	0	1	0	0	-
$^4 8_{5/2}[70, 1_2^-]$	2055	0	0	0	0	0	0	0	0	-

U(7) Sigma* missing states III

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$
$^2 10_{1/2}[70, 1_1^-]$	1755	4	5	4	11	–	1	30
$^2 10_{3/2}[70, 1_1^-]$	1755	9	6	14	0	–	181	165
$^2 10_{1/2}[70, 0_1^+]$	1863	0	1	0	1	0	45	39
$^4 10_{1/2}[56, 2_1^+]$	2012	12	18	16	35	14	21	17
$^4 10_{3/2}[56, 2_1^+]$	2012	6	9	8	18	7	79	69
$^4 10_{5/2}[56, 2_1^+]$	2012	11	7	15	1	0	112	101
$^2 10_{3/2}[70, 2_1^+]$	2037 ‡	1	1	1	2	1	38	42
$^2 10_{5/2}[70, 2_1^+]$	2037	5	4	7	1	0	63	56
$^2 10_J[70, 2_1^-]$	2037	0	0	0	0	0	0	0
$^4 10_{3/2}[56, 0_2^+]$	1765 ‡	8	8	9	1	–	13	38
$^2 10_{1/2}[70, 1_2^-]$	1996	0	0	0	0	0	0	0
$^2 10_{3/2}[70, 1_2^-]$	1996	0	0	0	0	0	0	0

$U(7)$ Model Results, arXiv:1506.07469 Missing resonances

TABLE XI: As Table VIII, but for missing Λ (top) and Λ^* (bottom) resonances.

Λ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$\Sigma^*\pi$	$\Xi^* K$	$N\overline{K}^*$	$\Sigma\rho$	$\Lambda\omega$
$^48_{3/2}[70,1_1^-]$	1799	0	15	1	–	447	–	–	–	–
$^28_J[20,1_1^+]$	1826	0	0	0	0	0	–	–	–	–
$^48_{3/2}[70,0_1^+]$	1904	0	3	4	2	54	–	0	–	0
$^28_{3/2}[70,2_1^+]$	1978	27	6	4	10	31	–	56	1	4
$^28_{5/2}[70,2_1^+]$	1978	109	12	2	1	58	–	123	3	16
$^28_J[70,2_1^-]$	1978	0	0	0	0	0	–	0	0	0
$^48_J[70,2_1^-]$	2074	0	0	0	0	0	0	0	0	0
$^48_{1/2}[70,2_1^+]$	2075	0	13	11	12	17	1	0	20	9
$^48_{3/2}[70,2_1^+]$	2075	0	6	6	6	82	4	0	28	13
$^48_{7/2}[70,2_1^+]$	2075	0	51	10	2	57	0	0	1	2
$^28_J[70,1_2^-]$	1936	0	0	0	0	0	–	0	–	0
$^48_{1/2}[70,1_2^-]$	2034	0	0	0	0	0	0	0	0	0
$^48_{3/2}[70,1_2^-]$	2034	0	0	0	0	1	0	0	0	0
$^48_{5/2}[70,1_2^-]$	2034	0	0	0	0	0	0	0	0	0
$^21_{1/2}[70,0_1^+]$	1756	29	44	14	–			–	–	–
$^41_J[20,1_1^+]$	1891	0	0	0	0			0	–	–
$^21_{3/2}[70,2_1^+]$	1939	35	66	36	17			39	–	6
$^21_{5/2}[70,2_1^+]$	1939	88	85	10	0			94	–	15
$^21_J[70,2_1^-]$	1939	0	0	0	0			0	–	0
$^21_J[70,1_2^-]$	1896	0	0	0	0			0	–	0

3* and 4* states

TABLE XV: Strong decay widths of three- and four-star nucleon resonances (in MeV), calculated with the Hypercentral QM of Sec. II B and Refs. [41, 46], in combination with the relativistic phase space factor (RPSF) of Eq. (21) and the values of the model parameters of Table XIV. The experimental values are taken from Ref. [1]. Decay channels labeled by – are below threshold. The symbols (S) and (D) stand for S and D-wave decays, respectively.

Resonance	Status	M [MeV]	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$N\rho$	$N\omega$	
$N(1440)P_{11}$	****	1430-1470	$110-338$	$0-5$			$22-101$			Exp.
$^28_{1/2}[56,0_2^+]$		1550	105	–	–	–	12	–	–	RPSF
$N(1520)D_{13}$	****	1515-1530	102	0			342			Exp.
$^28_{3/2}[70,1_1^-]$		1525	111	0	–	–	206	–	–	RPSF
$N(1535)S_{11}$	****	1520-1555	$44-96$	$40-91$			< 2			Exp.
$^28_{1/2}[70,1_1^-]$		1525	84	50	–	–	6	–	–	RPSF
$N(1650)S_{11}$	****	1640-1680	$60-162$	$6-27$		$4-20$	$0-45$			Exp.
$^28_{1/2}[70,1_2^-]$		1574	51	29	–	0	4	–	–	RPSF
$N(1675)D_{15}$	****	1670-1685	$46-74$	$0-2$		< 2	$65-99$			Exp.
$^48_{5/2}[70,1_1^-]$		1579	41	9	–	–	85	–	–	RPSF
$N(1680)F_{15}$	****	1675-1690	$78-98$	$0-1$			$6-21$			Exp.
$^28_{5/2}[56,2_1^+]$		1798	91	0	0	0	92	–	–	RPSF
$N(1700)D_{13}$	***	1650-1750	$7-43$	$0-3$		< 8	$10-225$ (S)			Exp.
							< 50 (D)			
$^28_{3/2}[70,1_2^-]$		1606	0	0	0	0	0	–	–	RPSF
$N(1710)P_{11}$	***	1680-1740	$3-50$	$5-75$		$3-63$	$8-100$	$3-63$		Exp.
$^28_{1/2}[70,0_1^+]$		1808	18	12	0	14.1	70	–	–	RPSF
$N(1720)P_{13}$	****	1650-1750	$12-56$	$5-20$		$2-60$	$90-360$	$105-340$		Exp.
$^28_{3/2}[56,2_1^+]$		1797	141	8	0	12	30	77	5	RPSF
$N(1875)D_{13}$	***	1820-1920	$3-70$	$0-22$	$0-4$		$48-192$ (S)	$0-38$	$22-90$	Exp.
							$11-86$ (D)			Exp.
$^48_{3/2}[70,1_1^-]$		1899	14	8	2	0	560	80	82	RPSF
$N(1900)P_{13}$	***	1875-1935	$20-37$	$24-44$	$6-26$	$0-37$			$75-120$	Exp.
$^28_{3/2}[70,2_1^+]$		1853	15	12	1	13	70	53	23	RPSF

Results for Hypercentral Model

3* and 4* states

TABLE XVI: As Table III, but for Δ resonances. The symbols (S), (P), (D) and (F) stand for S-, P-, D- and F-wave decays, respectively.

Resonance	Status	M [MeV]	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$	
$\Delta(1232)P_{33}$	****	1230-1234	$114-120$						Exp.
$^4 10_{3/2}[56, 0_1^+]$		1240	63	–	–	–	–	–	RPSF
$\Delta(1600)P_{33}$	***	1550-1700	$22-105$		$88-294$			< 88	Exp.
$^4 10_{3/2}[56, 0_2^+]$		1727	31	–	69	–	–	–	RPSF
$\Delta(1620)S_{31}$	****	1615-1675	$26-45$		$39-90$			$9-38$	Exp.
$^2 10_{1/2}[70, 1_1^-]$		1584	9	–	59	–	–	–	RPSF
$\Delta(1700)D_{33}$	****	1670-1770	$20-80$		$50-200$ (S) $10-60$ (D)	$6-28$		$48-165$	Exp.
$^2 10_{3/2}[70, 1_1^-]$		1584	40	–	333	–	–	–	RPSF
$\Delta(1905)F_{35}$	****	1855-1910	$24-60$		< 100			> 162	Exp.
$^4 10_{5/2}[56, 2_1^+]$		1844	26	0	182	15	–	88	RPSF
$\Delta(1910)P_{31}$	****	1860-1910	$33-102$	$9-48$	$70-299$				Exp.
$^4 10_{1/2}[56, 2_1^+]$		1871	49	38	34	4	–	60	RPSF
$\Delta(1920)P_{33}$	***	1900-1970	$9-60$	$3-7$	$18-102$ (P) $45-195$ (F)	$13-69$		0	Exp.
$^4 10_{3/2}[56, 2_1^+]$		1856	17	22	137	20	–	102	RPSF
$\Delta(1950)F_{37}$	****	1940-1960	$82-151$	$1-2$	$47-101$			< 34	Exp.
$^4 10_{7/2}[56, 2_1^+]$		1851	146	3	70	1	–	16	RPSF

TABLE XVII: Strong decay widths of missing nucleon resonances (in MeV), calculated with the Hypercentral QM of Sec. II B and Refs. [41, 46], in combination with the relativistic phase space factor of Eq. (21) and the values of the model parameters of Table XIV. Tentative assignments of one and two star resonances are labeled by ‡.

N	Mass	$N\pi$	$N\eta$	ΣK	ΛK	$\Delta\pi$	$\Sigma^* K$	$N\rho$	$N\omega$	ΣK^*	ΛK^*	$\Delta\rho$
$^4 8_{3/2}[70, 2_1^+]$	1835	4	8	7	0	97	-	8	7	-	-	-
$^2 8_{1/2}[20, 1_1^+]$	1836	0	0	0	0	0	-	0	0	-	-	-
$^2 8_{3/2}[20, 1_1^+]$	1836	0	0	0	0	0	-	0	0	-	-	-
$^4 8_{1/2}[70, 2_1^+]$	1839 ‡	8	16	15	0	27	-	6	5	-	-	-
$^4 8_{7/2}[70, 2_1^+]$	1840 ‡	12	4	0	0	25	-	0	0	-	-	-
$^4 8_{5/2}[70, 2_1^+]$	1844 ‡	3	1	0	0	137	-	9	8	-	-	-
$^4 8_{5/2}[70, 2_1^+]$	1851 ‡	3	1	0	0	137	-	9	9	-	-	-
$^4 8_{3/2}[70, 0_1^+]$	1863 ‡	0	4	22	0	83	-	12	12	-	-	-
$^4 8_{1/2}[70, 1_1^-]$	1887 ‡	0	22	119	0	87	-	32	32	-	-	-
$^4 8_{1/2}[70, 1_2^-]$	1937	0	0	0	0	0	-	0	0	-	-	-
$^4 8_{5/2}[70, 1_2^-]$	1942 ‡	0	0	0	0	0	0	0	0	-	-	-
$^2 8_{1/2}[56, 0_3^+]$	1943 ‡	0	0	0	0	0	0	0	0	-	-	-
$^4 8_{3/2}[70, 1_2^-]$	1969	0	0	0	0	0	0	0	0	-	-	-

TABLE XVIII: As Table XVII, but for missing Δ resonances.

Δ	Mass	$N\pi$	ΣK	$\Delta\pi$	$\Delta\eta$	$\Sigma^* K$	$N\rho$
$^{2}10_{1/2}[70, 0_1^+]$	1832 ‡	0	2	89	7	-	57
$^{2}10_{3/2}[70, 2_1^+]$	1843	4	1	43	1	-	51
$^{2}10_{1/2}[70, 1_2^-]$	1947 ‡	0	0	1	0	0	0
$^{2}10_{3/2}[70, 1_2^-]$	1947 ‡	0	0	1	0	0	0
$^{2}10_{5/2}[70, 2_1^+]$	1859 ‡	10	0	97	7	-	13
$^{4}10_{3/2}[56, 0_3^+]$	2103	0	0	0	0	0	0

TABLE XIX: As Table XVII, but for missing Σ (top) and Σ^* (bottom) resonances.

Σ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\pi$	$\Sigma\eta$	ΞK	$\Delta\overline{K}$	$\Sigma^*\pi$	$\Sigma^*\eta$	$\Xi^* K$	$N\overline{K}^*$	$\Sigma\rho$	$\Lambda\rho$	$\Sigma\omega$	$\Delta\overline{K}$
$^2 8_{3/2}[56, 2_1^+]$	1906	4	69	22	19	20	20	7	–	–	21	–	–	–	–
$^4 8_{1/2}[70, 1_1^-]$	1914	9	7	3	17	22	22	9	–	–	100	–	–	–	–
$^2 8_{1/2}[56, 0_3^+]$	2050 †	0	0	0	0	0	0	0	–	–	0	–	–	–	–
$^2 8_{3/2}[70, 2_1^+]$	2072	1	31	1	7	16	39	11	–	–	29	–	–	–	–
$^2 8_{5/2}[70, 2_1^+]$	2072	5	89	7	3	3	66	15	–	–	11	–	–	–	–
$^2 8_{1/2}[70, 1_2^-]$	2149	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$^4 8_{1/2}[70, 2_1^+]$	2187	3	2	1	3	4	16	3	5	1	21	6	9	2	16
$^4 8_{3/2}[70, 2_1^+]$	2187	1	1	1	1	2	91	21	17	5	40	10	15	3	18
$^4 8_{5/2}[70, 2_1^+]$	2187	19	3	6	1	0	147	34	23	6	52	10	18	3	49
$^4 8_{7/2}[70, 2_1^+]$	2187	83	15	29	2	1	83	21	3	0	30	2	7	1	159
$^2 8_J[20, 1_1^+]$	2238	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$^4 8_J[70, 1_2^-]$	2263	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$^4 10_{3/2}[56, 0_2^+]$	1883	6	9	8	11	2	68	63	–	–	14	–	–	–	–
$^4 10_{3/2}[56, 2_1^+]$	2085	6	9	9	18	8	86	76	2	–	39	25	53	19	–
$^2 10_{3/2}[70, 2_1^+]$	2136	0	1	1	2	1	61	63	0	2	29	25	43	20	1
$^2 10_{5/2}[70, 2_1^+]$	2136	7	5	9	2	0	70	63	1	10	17	7	18	5	4
$^2 10_J[70, 1_2^-]$	2212	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Results for Hypercentral Model

Missing resonances

TABLE XXI: As Table XVII, but for missing Ξ (top) and Ξ^* (bottom) resonances.

Ξ	Mass	$\Sigma\overline{K}$	$\Lambda\overline{K}$	$\Xi\pi$	$\Xi\eta$	$\Sigma^*\overline{K}$	$\Xi^*\pi$	$\Lambda\overline{K}^*$	$\Sigma\overline{K}^*$	$\Xi\rho$	$\Xi\omega$
$^2 8_{1/2}[56, 0_2^+]$	1843	125	6	5	–	–	15	–	–	–	–
$^4 8_{3/2}[70, 1_1^-]$	2053	8	11	37	0	223	154	–	–	–	–
$^2 8_{1/2}[56, 0_3^+]$	2190	0	0	0	0	0	0	0	0	0	0
$^2 8_{1/2}[70, 1_2^-]$	2288	0	0	0	0	0	0	0	0	0	0
$^2 8_{3/2}[70, 1_2^-]$	2288	0	0	0	0	0	0	0	0	0	0
$^4 8_{1/2}[70, 2_1^+]$	2327	3	1	8	1	6	5	8	10	40	1
$^4 8_{3/2}[70, 2_1^+]$	2327	2	1	4	0	35	32	16	16	62	1
$^4 8_{5/2}[70, 2_1^+]$	2327	6	7	24	0	57	53	20	18	69	1
$^4 8_{7/2}[70, 2_1^+]$	2327	26	33	108	1	33	33	11	5	16	0
$^2 8_J[20, 1_1^+]$	2377	0	0	0	0	0	0	0	0	0	0
$^4 8_J[70, 1_2^-]$	2403	0	0	0	0	0	0	0	0	0	0
$^4 10_{3/2}[56, 0_2^+]$	2022	19	12	13	12	–	24	–	–	–	–
$^4 10_{1/2}[56, 2_1^+]$	2225	33	19	23	35	33	7	40	34	31	16
$^4 10_{3/2}[56, 2_1^+]$	2225	17	10	12	17	133	29	61	50	44	23
$^4 10_{5/2}[56, 2_1^+]$	2225	14	19	16	3	194	44	66	51	45	24
$^4 10_{7/2}[56, 2_1^+]$	2225	64	87	70	13	56	16	13	3	2	1
$^2 10_{1/2}[70, 1_2^-]$	2352	0	0	0	0	0	0	0	0	0	0
$^2 10_{3/2}[70, 1_2^-]$	2352	0	0	0	0	1	0	0	0	0	0
$^4 10_{3/2}[56, 0_3^+]$	2369	0	0	0	0	0	0	0	0	0	0

Results for Hypercentral Model

Missing resonances

Λ	Mass	$N\overline{K}$	$\Sigma\pi$	$\Lambda\eta$	ΞK	$\Sigma^*\pi$	$\Xi^* K$	$N\overline{K}^*$	$\Sigma\rho$	$\Lambda\omega$
${}^4 8_{3/2}[70, 1_1^-]$	1837	0	15	2	–	477	–	–	–	–
${}^2 8_{3/2}[70, 2_1^+]$	1995	38	8	0	10	29	–	55	2	4
${}^2 8_{1/2}[70, 1_2^-]$	2072	0	0	0	0	0	–	0	–	0
${}^2 8_{3/2}[70, 1_2^-]$	2072	0	0	0	0	0	0	0	0	0
${}^4 8_{3/2}[70, 0_1^+]$	2110	0	0	1	4	35	11	0	41	8
${}^4 8_{1/2}[70, 2_1^+]$	2110	0	18	13	12	35	2	0	23	9
${}^4 8_{3/2}[70, 2_1^+]$	2110	0	10	6	2	87	7	0	33	14
${}^4 8_{7/2}[70, 2_1^+]$	2110	0	50	10	2	19	0	0	2	2
${}^2 8_J[20, 1_1^+]$	2160	0	0	0	0	0	0	0	0	0
${}^4 8_{1/2}[70, 1_2^-]$	2186	0	0	0	0	0	0	0	0	0
${}^4 8_{3/2}[70, 1_2^-]$	2186	0	0	0	0	1	0	0	0	0
${}^4 8_{5/2}[70, 1_2^-]$	2186	0	0	0	0	0	0	0	0	0
${}^2 1_{1/2}[70, 1_2^-]$	2008	0	1	0	0	–	–	1	–	0
${}^2 1_{3/2}[70, 1_2^-]$	2008	0	0	0	0	–	–	0	–	0

Results for Hypercentral Model — Missing resonances

TABLE XXII: As Table XVII, but for missing Ω resonance

Ω	Mass	$\Xi\overline{K}$	$\Xi^*\overline{K}$	$\Omega\eta$	$\Xi\overline{K}^*$
$^{2}10_{1/2}[70, 1_1^-]$	2142	26	48	–	–
$^{2}10_{3/2}[70, 1_1^-]$	2142	68	403	–	–
$^{4}10_{3/2}[56, 0_2^+]$	2162	68	102	–	–
$^{4}10_{1/2}[56, 2_2^+]$	2364	109	34	27	155
$^{4}10_{3/2}[56, 2_2^+]$	2364	55	137	88	225
$^{4}10_{5/2}[56, 2_2^+]$	2364	69	199	117	234
$^{4}10_{7/2}[56, 2_2^+]$	2364	308	58	4	23
$^{2}10_{1/2}[70, 1_2^-]$	2492	0	0	0	0
$^{2}10_{3/2}[70, 1_2^-]$	2492	0	1	0	0
$^{4}10_{3/2}[56, 0_3^+]$	2508	0	0	0	0

Comparison

- We computed the open-flavor strong decays of light baryons (i.e. made up of u, d, s valence quarks) into baryon-pseudoscalar and baryon- vector mesons using a $^3P_0$ pair-creation model.
- We studied the strong decays in two different constituent quark Models. Some resonances have different assignments then we have different predictions.
- We to suppress heavier quark pair creation, like $s\bar{s}$ with respect to $u\bar{u}(d\bar{d})$
- A large number of decays were described with a few parameters.
- Maybe the deviations are due to the meson cloud effects or the contribution of the higher Fock components.

We extended the predictions of Capstick and Roberts in the 3P0 model to the hyperons and we also included the decays into baryons + vector mesons.

We calculated the strong decays 3P0 predictions for two models: the U(7) and the hypercentral: they came out to be different in particular for the missing states

For the first time 3P0 decays have been calculated for baryons taking into account the strangeness suppression and all the analytical formula and couplings are in the appendix in closed form-→ so they can be used with other models.

Different quark models have different missing states and so different predictions (but also in some known states they can give different predictions)-→>> tool to distinguish between Different models of structure.

Thanks !

One may wonder whether there is a unique spectral signature for quark-diquark models. One of these signatures is the detection of 1^+ states which are antisymmetric in all three quarks. These states, originating from the omitted diquark representation **15** of $SU_{sf}(6)$ are not present in the quark-diquark model and occur (at different masses) in all models with three quarks. These missing states may, however, be very difficult to detect since they are decoupled and cannot be excited with electrons or photons. To excite these states, strongly interacting particles are needed, for example $(\vec{p}, \vec{p'})$ with spin transfer. Another possibility

E. Santopinto, PRC72, 022201 (2005)

TABLE II: ${}^3P_0$ model parameter values used in the calculations, in combination with the relativistic phase space factor of Eq. (21) (column 2) and the effective phase space factor of Eq. (22) (column 3). The parameter values are obtained in a fit to the experimental strong decay widths. See App. A, Table XXIII, last column. The values of the constituent quark masses m_n ($n = u, d$) and m_s are used in the vertex factor of Eq. (A2), where the pair-creation strength, γ_0, is substituted by an effective one [see Eq. (24)]. α_b is the harmonic oscillator parameter of baryons A and B, α_c that of meson C and α_d is the quark form factor parameter.

Parameter	Rel. PSF	Eff. PSF
γ_0	14.3	13.2
α_b	2.99 GeV^{-1}	2.69 GeV^{-1}
α_c	2.38 GeV^{-1}	2.02 GeV^{-1}
α_d	0.52 GeV^{-1}	0.82 GeV^{-1}
m_n	0.33 GeV	
m_s	0.55 GeV	

TABLE XIV: Parameter values used in the calculations, in combination with the relativistic phase space factor of Eq. (21). The parameter values are fitted to a sample of 9 transitions: $\Delta \to N\pi$, $N(1520) \to N\pi$, $N(1535) \to N\pi$, $N(1650) \to N\pi$, $N(1680) \to N\pi$, $N(1720) \to N\pi$, $\Delta(1905) \to N\pi$, $\Delta(1910) \to N\pi$ and $\Delta(1920) \to N\pi$. The quantum number assignments for the decaying states are now taken from the hQM results of Ref. [41, 46] and Table XV.

Parameter	Value
γ_0	13.319
α_b	2.758
α_c	2.454
α_d	0
m_n	0.33
m_s	0.55