Magnetic Moment, Mass, Spin and Strangeness of Hyperons

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Abstract: Here within the lacking part of ultimate theory, i.e. the Everlasting Theory, I calculated the magnetic moments and rigorous masses of hyperons. The theoretical results overlap with experimental data or are very close to them. The obtained spins and strangeness of hyperons are consistent with experimental results as well.

1. Introduction

The lacking part of ultimate theory, i.e. the Everlasting Theory, is based on two fundamental axioms [1]. There are the phase transitions of the fundamental spacetime composed of the superluminal and gravitationally massless pieces of space (the tachyons). The phase transitions follow from the saturated interactions of the tachyons and lead to the superluminal binary systems of closed strings responsible for the entanglement, to the binary systems of neutrinos i.e. to the Einstein-spacetime components, to the cores of baryons and to the cosmic objects that appeared after the era of inflation but before the observed expansion of our Universe. The second axiom follows from the symmetrical decays of bosons that appear on the surface of the core of baryons. It leads to the Titius-Bode law for the strong interactions i.e. to the atom-like structure of baryons. Within such theory I calculated the relative magnetic moments of proton and neutron [1]: for proton is R_{proton} = +2.79360 whereas for neutron $R_{neutron}$ = –1.91343.

Internal structure of the hyperons is as follows [1] (the values of the approximate masses are in MeV)

$$m_{\Lambda} = m_{neutron} + M_{(o),k=0,d=2} = 1115.3, \tag{1}$$

$$m_{\Sigma(+)} = m_{proton} + M_{(o),k=2,d=2} = 1189.6, \tag{2}$$

$$m_{\Sigma(o)} = m_{neutron} + M_{(o),k=2,d=2} = 1190.9, \tag{3}$$

$$m_{\Sigma(-)} = m_{neutron} + M_{(-),k=2,d=2} = 1196.9, \tag{4}$$

$$m_{\Xi(o)} = m_{\Lambda} + M_{(o),k=1,d=2} = 1316.2, \tag{5}$$

$$m_{\Xi(-)} = m_{\Lambda} + M_{(-),k=1,d=2} = 1322.2, \tag{6}$$

$$m_{\Omega(-)} = m_{\Xi(-o)} + M_{(o-),k=3,d=2} = 1674.4. \tag{7}$$

Following formula defines the masses $M_{(+-o),k,d}$ [1]

$$M_{(+-o),k,d=2} = m_{W(+-o),d=2} + \sum_{d=0,1,2,4}^{d<2^k} dE_W, \tag{8}$$

where k = 0, 1, 2, 3 whereas E_W = 25.213 MeV. The k and d determine quantum state of particle having a mass $M_{(+-o),k,d}$. The mass of a hyperon is equal to the sum of the mass of a nucleon and of the masses calculated from (8). The $m_{W(+-o),d=2}$ is the relativistic mass of pion in the d = 2 state defined by the Titius-Bode law for the strong interactions ($m_{W(+-),d=2}$ = 181.704 MeV whereas $m_{W(o),d=2}$ = 175.709 MeV.

The number of the relativistic W pions in the d = 2 state, i.e. in the ground state above the Schwarzschild surface for the strong interactions [1], taken with the sign "–" defines the strangeness of a hyperon.

The Everlasting Theory [1] defines as well a probability that the y proton is composed of the charged core H^+ and relativistic neutral pion $W_{(o),d=1}$ and a probability that 1-y is composed of H^o and $W_{(+),d=1}$. From the Heisenberg uncertainty principle follows that the probabilities y and 1-y, which are associated with the lifetimes of protons in the above-mentioned states, are inversely proportional to the relativistic masses of the W pions

$$y = m_{pion(+-)}/(m_{pion(+-)} + m_{pion(o)}) = 0.5083856, \qquad (9)$$

$$1 - y = m_{pion(o)}/(m_{pion(+-)} + m_{pion(o)}) = 0.4916144. \qquad (10)$$

There is a probability that the x neutron is composed of H^+ and $W_{(-),d=1}$ and a probability that 1-x is composed of H^o, resting neutral pion and Z^o. The mass of the last particle is $m_{Z(o)}=m_{W(o),d=1}-m_{pion(o)}$. The probabilities are as follows

$$x = m_{pion(o)}/m_{W(-),d=1} = 0.6255371, \qquad (11)$$

$$1 - x = 0.3744629. \qquad (12)$$

2. Calculations

The relative magnetic moments are equal to the ratio of the mass of proton (mass is 938.272 [1]) to mass of a charged component. For the charged core of baryons H^+ (mass is 727.44 MeV [1]) we obtain

X = +938.27/727.44 = +1.28983.

For $W_{(+-),d=1}$ (mass is 215.760 MeV [1]) is

Y_{+-} = ±938.27/215.760 = ±4.34868.

For $W_{(-),k=0,d=2}$ (mass is 181.704 MeV [1]) is

Z_1 = –938.27/181.704 = –5.16374.

For $W_{(-),k=1,d=2}$ (mass is 181.704 + 1·25.213 = 206.917 MeV – see formula (8)) is

Z_2 = –938.27/206.917 = –4.53453.

For $W_{(-),k=2,d=2}$ (mass is 181.704 + 3·25.213 = 257.343 MeV – see formula (8)) is

Z_3 = –938.27/257.343 = –3.64600.

For $W_{(+),k=2,d=2}$ is Z_4 = +938.27/257.343 = +3.64600.

For $W_{(-),k=3,d=2}$ (mass is 181.704 + 7·25.213 = 358.195 MeV – see formula (8)) is

Z_5 = –938.27/358.195 = –2.61944.

Hyperon Lambda

Composition of the hyperon Λ is

$\Lambda = n + W_{(o),k=0,d=2} = (\mathbf{A} + \mathbf{F} + L)/\mathbf{3} + (B + G + L)/3 + (Be^+ + Ge^- + L)/3$.

The Everlasting Theory shows that electric charge of electron is defined by torus composed of the Einstein-spacetime components [1]. The mean radius of the torus is equal to 2/3 of the reduced Compton radius of electron. This means that the electric radius of electron interacting weakly with a baryon lies outside the baryon so the electric charge does not give a contribution to magnetic moment of the baryon. It is very difficult to localize the electric charge of electron because the torus is only specifically polarized the Einstein spacetime [1]. This leads to conclusion that only the first component (precisely the A and F) gives contribution to the relative magnetic moment and it is the relative magnetic moment of neutron. Assume that probabilities for the all three components are the same so the relative magnetic moment R_Λ is

$R_\Lambda = R_{neutron}/3 \approx -0.64$.

In the third state of the hyperon Λ, the sum of the masses of H^o and $e^+\nu_e$ is equal to the mass of H^+ whereas of $W_{(o),d=1}$ and $e^-\nu_{e,anti}$ is equal to the mass of $W_{(-),d=1}$. We can see that the mean mass of the hyperon Lambda is 1115.649 MeV.

In each state of the hyperon Lambda defined by the contents of a bracket (…), is only one pion W in the d = 2 state so the strangeness of the hyperon Lambda is –1.

In each state of the hyperon Lambda there is only the half-integral spin of the core of hyperons whereas there is lack of the unitary spins of the vector bosons E_W that appear in formula (8). This means that the spin of hyperon Lambda is 1/2.

Table 1 *Relative magnetic moments of constituents of hyperons*

Constituent	**Mass [MeV]**	**Relative magnetic moment Everlasting Theory**
$A = H^+$	727.440	$X_o = +1.28983$
$B = H^o$	724.777	0
$Be^+ = (H^o + e^+\nu_e)$	727.440	does not concern
$e^- = e^-\nu_{e,anti}$	0.511	does not concern
$E = W_{(+),d=1}$	215.760	$Y_+ = +4.34868$
$F = W_{(-),d=1}$	215.760	$Y_- = -4.34868$
$G = W_{(o),d=1}$	208.643	0
$Ge^- = (W_{(o),d=1} + e^-\nu_{e,anti})$	215.760	does not concern
$K = W_{(-),k=0,d=2}$	181.704	$Z_1 = -5.16374$
$L = W_{(o),k=0,d=2}$	175.709	0
$Le^- = (W_{(o),k=0,d=2} + e^-\nu_{e,anti})$	181.704	does not concern
$M = W_{(-),k=1,d=2}$	206.917	$Z_2 = -4.53453$
$P = W_{(o),k=1,d=2}$	200.922	0
$Pe^- = (W_{(o),k=1,d=2} + e^-\nu_{e,anti})$	206.917	does not concern
$S = W_{(-),k=2,d=2}$	257.343	$Z_3 = -3.64600$
$T = W_{(+),k=2,d=2}$	257.343	$Z_4 = +3.64600$
$U = W_{(o),k=2,d=2}$	251.348	0
$Ue^- = (W_{(o),k=2,d=2}.+ e^-\nu_{e,anti})$	257.343	does not concern
$Y = W_{(-),k=3,d=2}$	358.195	$Z_5 = -2.61944$
$Z = W_{(o),k=3,d=2}$	352.200	0
$Ze^- = (W_{(o),k=3,d=2}.+ e^-\nu_{e,anti})$	358.195	does not concern

Hyperon Sigma$^+$

Composition of the hyperon Σ^+ is

$\Sigma^+ = \mathbf{y}(\mathbf{A} + G + U) + \mathbf{(1\text{-}y)}(B + G + \mathbf{T})$.

The relative magnetic moment $R_{\Sigma(+)}$ is

$R_{\Sigma(+)} = yX_o + (1 - y)Z_4 = +2.4482$

whereas the mass is 1189.069 MeV.

In each state of the hyperon Sigma$^+$ defined by the contents of a bracket (…), is only one pion W in the d = 2 state so the strangeness of the hyperon Sigma$^+$ is –1.

The arrangement of spins in each state of the hyperon Sigma$^+$ is as follows.

↑ and $\underbrace{\downarrow\uparrow}_{k\,=\,2}$ + ↓ spin = 1/2

The smaller arrow denotes the half-integral spin of the core of hyperon whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8). The vector bosons E_W behave in the strong fields inside baryons as the electrons in the electromagnetic fields inside atoms. This leads to conclusion that the spins of the vector bosons are oriented in accordance with the Hund law. The spins of the core and vector bosons E_W are oriented in such a way that the total angular momentum of a hyperon has minimal value but the spins of the vector bosons must be oriented in accordance with the Hund law. All of the relativistic pions are in the S state.

Hyperon Sigma^o

Composition of the hyperon Σ^o is similar to hyperon Λ but instead the $W_{(o),k=0,d=2}$ there is the $W_{(o),k=2,d=2}$:

$\Sigma^o = n + W_{(o),k=2,d=2} = (\mathbf{A} + \mathbf{F} + U)/\mathbf{3} + (B + G + U)/3 + (Be^+ + Ge^- + U)/3.$

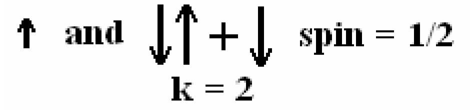
This difference does not change the relative magnetic moment so the relative magnetic moment $R_{\Sigma(o)}$ is

$R_{\Sigma(o)} = R_\Lambda \approx -0.64$

whereas the mass is 1191.288 MeV.

In each state of the hyperon Sigma^o defined by the contents of a bracket (…), is only one pion W in the d = 2 state so the strangeness of the hyperon Sigma^o is –1.

The arrangement of spins in each state of the hyperon Sigma^o is as follows.



The smaller arrow denotes the half-integral spin of the core of hyperon whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8).

Hyperon Sigma$^-$

Composition of the hyperon Σ^- is

$\Sigma^- = (\mathbf{A} + Ge^- + \mathbf{S})/\mathbf{2} + (Be^+ + G + e^- + Ue^-)/2.$

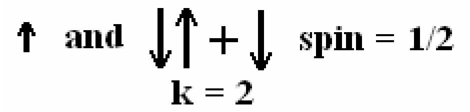
The relative magnetic moment $R_{\Sigma(-)}$ is

$R_{\Sigma(-)} = (X_o + Z_3)/2 = -1.1781$

whereas the mass is 1197.240 MeV.

In each state of the hyperon Sigma$^-$ defined by the contents of a bracket (…), is only one pion W in the d = 2 state so the strangeness of the hyperon Sigma$^-$ is –1.

The arrangement of spins in each state of the hyperon Sigma$^-$ is as follows.



The smaller arrow denotes the half-integral spin of the core of hyperons whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8).

Hyperon Xi^o

There are the two states of neutron i.e. the charged and uncharged. The uncharged state does not give a contribution to the mean relative magnetic moment (it is the mean magnetic moment in the nuclear magneton). Assume that probabilities of these two states for hyperons are the same so there appears the factor f = 1/2.

Composition of the hyperon Ξ^o is

$\Xi^o = \{\mathbf{x}\,(\mathbf{A} + G + \mathbf{K} + P) + (1 - x)(Be^+ + G + Le^- + P)\}/\mathbf{2} + (B + G + L + P)/2.$

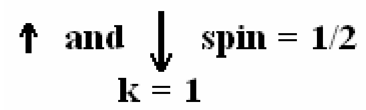
The relative magnetic moment $R_{\Xi(o)}$ is

$R_{\Xi(o)} = x\,(X_o + Z_1)/2 = -1.2116$

whereas the mass is 1314.380 MeV.

In each state of the hyperon Xi^o defined by the contents of a bracket (…), are two pions W in the d = 2 state so the strangeness of the hyperon Xi^o is –2.

The arrangement of spins in each state of the hyperon Xi^o is as follows.



The smaller arrow denotes the half-integral spin of the core of hyperons whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8).

Hyperon Xi^-

Composition of the hyperon Ξ^- is

$\Xi^- = \{\mathbf{(1 - x)}(\mathbf{A} + Ge^- + L + \mathbf{M}) + x\,(Be^+ + G + Le^- + Pe^-)\}/\mathbf{2} + (B + Ge^- + L + P)/2.$

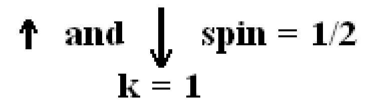
The relative magnetic moment $R_{\Xi(-)}$ is

$R_{\Xi(-)} = (1 - x)(X_o + Z_2)/2 = -0.6075$

whereas the mass is 1321.146 MeV.

In each state of the hyperon Xi^- defined by the contents of a bracket (…), are two pions W in the d = 2 state so the strangeness of the hyperon Xi^- is –2.

The arrangement of spins in each state of the hyperon Xi^- is as follows.



The smaller arrow denotes the half-integral spin of the core of hyperons whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8).

Hyperon $Omega^-$

Composition of the hyperon Ω^- is

$\Omega^- = \Xi^o + Y(\text{or } Ze^-) = \{\mathbf{x}\,(\mathbf{A} + G + \mathbf{K} + P + \mathbf{Y}) + (1 - x)(Be^+ + G + Le^- + P + Ze^-)\}/\mathbf{2} +$
$+ (B + G + L + P + Ze^-)/2.$

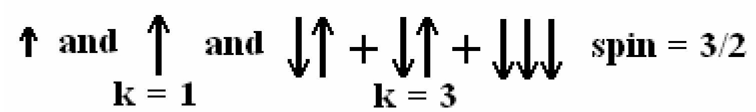
The relative magnetic moment $R_{\Omega(-)}$ is

$R_{\Omega(-)} = x\,(X_o + Z_1 + Z_5)/2 = -2.0309$

whereas the mass is 1672.575 MeV.

In each state of the hyperon $Omega^-$ defined by the contents of a bracket (…), are three pions W in the d = 2 state so the strangeness of the hyperon $Omega^-$ is –3.

The arrangement of spins in each state of the hyperon $Omega^-$ is as follows.



The smaller arrow denotes the half-integral spin of the core of hyperons whereas the larger arrows the unitary spins of the vector bosons E_W that appear in formula (8).

3. Summary

Here within the lacking part of ultimate theory, i.e. the Everlasting Theory, I calculated the magnetic moments of hyperons. The theoretical results overlap with experimental data or are very close to them.

Table 2 *Relative magnetic moments*

Nucleon or Hyperon	**Relative magnetic moment PDG [2]**	**Relative magnetic moment Everlasting Theory**
Proton p	+2.792847356(23)	+2.79360 [1]
Neutron n	–1.9130427(5)	–1.91343 [1]
Hyperon Λ	-0.613 ± 0.004	–0.64
Hyperon Σ^+	$+2.458 \pm 0.010$	+2.4482
Hyperon Σ^o	?	–0.64
Hyperon Σ^-	-1.160 ± 0.025	–1.18
Hyperon Ξ^o	-1.250 ± 0.014	–1.21
Hyperon Ξ^-	-0.6507 ± 0.0025	–0.61
Hyperon Ω^-	-2.02 ± 0.05	–2.03

On base of the relative magnetic moments of hyperons we can calculate the rigorous masses. The obtained results are very good as well and are collected in Table 3.

Table 3 *Rigorous mass of hyperons*

Particle	**Experimental mass PDG [2]**	**Rigorous theoretical mass Everlasting Theory**
Hyperon Λ	1115.683 ± 0.006	1115.649 MeV
Hyperon Σ^+	1189.37 ± 0.07	1189.069 MeV
Hyperon Σ^o	1192.642 ± 0.024	1191.288 MeV
Hyperon Σ^-	1197.449 ± 0.030	1197.240 MeV
Hyperon Ξ^o	1314.86 ± 0.20	1314.380 MeV
Hyperon Ξ^-	1321.71 ± 0.07	1321.146 MeV
Hyperon Ω^-	1672.45 ± 0.29	1672.575 MeV

The calculated spin and strangeness of hyperons are collected in Table 4. They are consistent with experimental data.

Table 4 *Spin and strangeness of hyperons*

Particle	**Spin Everlasting Theory**	**Strangeness Everlasting Theory**
Hyperon Λ	1/2	–1
Hyperon Σ^+	1/2	–1
Hyperon Σ^o	1/2	–1
Hyperon Σ^-	1/2	–1
Hyperon Ξ^o	1/2	–2
Hyperon Ξ^-	1/2	–2
Hyperon Ω^-	3/2	–3

The lifetimes of the hyperons Xi^o and Xi^- are respectively $a = (2.90 \pm 0.09) \cdot 10^{-10}$ s and $b = (1.639 \pm 0.015) \cdot 10^{-10}$ s [2]. The ratio $a/(a + b)$ is close to the probability x so this probability should be associated with the magnetic moment of the hyperon Xi^o whereas the ratio $b/(a + b)$ is close to $1 - x$ so this probability should be associated with the magnetic moment of the hyperon Xi^-. It is consistent with presented here the theory of hyperons.

The experimental data show that the hyperon $Omega^-$ mostly decays into neutral hyperon Lambda and negatively charged kaon K^- (67.8 ± 0.07)% or neutral hyperon Xi^o and negatively charged pion π^- (23.6 ± 0.07)% [2]. It suggests that there should dominate the structure of the hyperon Omega$^-$ composed of the neutral hyperon Xi^o and negatively charged relativistic pion π^-. It follows as well from the fact that the neutral hyperon Xi^o is more stable (i.e. its lifetime is longer) than the negatively charged Xi$^-$. It is consistent with presented here the theory of hyperons also.

Notice also that the percentages for the main channels of the decay of Λ and Σ^+ hyperons are close to the x, 1-x, y, 1-y probabilities. This suggests that in a hyperon, before it decays, the $W_{(o),d=2}$ pion transits to the d=1 state and during its decay the pion appears which was in the d=1 state.

References

[1] S. Kornowski (3 December 2012). “The Everlasting Theory and Special Number Theory”.
http://www.rxiv.org/abs/1203.0021 [v2].
[2] K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37**, 075021 (2010) and 2011 partial update for the 2012 edition.