The Periodic variation of Baryon masses as a function of their Magnetic Moments: quantum interference in the femtometer scale of Hadrons.

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Abstract: The objective of this paper is to give full consideration to an important (never divulged) result which comes straight from *tabulated* data for all baryons of the octet and decuplet when these data are duly analyzed theoretically, namely: *The masses of spin ½ baryons, in proton mass-units, are a simple periodic function of their magnetic moments, in nuclear magneton-units.* As discussed here, this can be attributed to quantum interference of closed currents inside the particles, as observed in conventional superconducting rings confining magnetic flux.

keywords: Quantum interference, Regularization techniques, Casimir effect.

1) Introduction, and discussion of the theory in previous work.

In recent years the author has carried out investigations whose objective is to undertake the application of electrodynamics in the theoretical analysis of Particles properties, like in the determination of their masses, and their relation to magnetic flux confinement inside the Particle (see the papers by the author in vixra and references below). This led to the association of the origin of Particles to a topological transition(to a current loop-state) starting from plane waves in an environment at 10^{13} K (possibly Big Bang conditions) [1,2]. In view of the amount of data available, the analysis has been concentrated on the baryons of the octet and decuplet.

Quantitative agreement between models and data has been achieved adopting a relativistic circular loop of currents model for the baryons[1], in which is included the concept (introduced by Asim Barut in the 1970s [3]) that a proton-state m_{p} surrounded by a cloud of mesons and electrons is taken as a fundamental element present in all baryons. This is a model which is explicitly developed for spin ½ particles, since mass of such quasi-proton can circulate in two opposite directions. Making reference to details available in previous publications[1], a Dirac equation is written for the loop-shaped distribution of mass and charge that models a Particle. The motion of mass around the loop (of perimeter L) is the result of the propagation of local elemental displacements, like in a vibrating string. Bohr-Sommerfeld quantum conditions impose a periodicity that introduces an infinite number of vibrating modes (indexed as k), given by the momenta p_k below. The fundamental state is obtained by summing up over these modes. This sum diverges, but the converging part of the solution can be isolated by applying a Regularization (“Reg” below) procedure that extracts the diverging parts, which are associated to the surrounding infinite environment[1]. The Dirac equation and its solution include a magnetic gauge field A , which introduces an amount of magnetic flux ϕ arrested inside the loop. The flux $\phi = A\, L$ is defined in numbers n of magnetic flux quanta $\phi_0 = hc/e$. The solutions of the Dirac hamiltonian provide energies which are associated with the rest energies Mc^2 of the baryons, through the expression(s $\rightarrow$ -1).

$$M\, c^2 = U_0 + \mathrm{Reg} \sum\nolimits_k c\{(p_k + e\phi/Lc)^2 + m_p{}^2 c^2\}^{-S/2} \qquad (1)$$

for each baryon of mass M. Here U_0 is the parent state energy of the environment the loops originate from, and is obtained by comparing theory with the mass data for the baryons. Equation (1) can be rewitten in dimensionless form. Here the dimensionless parameters used are $m' = m_p/m_0$, where $m_0 = 2\pi\hbar/cL$, and $u_0 = U_0/m_p c^2$.

$$M(n)/m_p = u_0 + (1/m')\mathrm{Reg}\sum_k \{(k+n)^2 + m'^2\}^{-s/2} \qquad (2)$$

The second term on the right of (2) corresponds to a kind of internal correlation energy that turns the loop states energetically favorable as compared to the parent state, so some sort of condensation into loop forms takes place. This would be the picture of Particles formation from a Parent state. The Regularization of the second term in (2) results in(s→ -1):

$$\frac{2\sqrt{\pi}}{\Gamma\left(\frac{1-s}{2}\right)}\left(\frac{\Gamma\left(-\frac{s}{2}\right)}{2m'^{\,-s}} + 2\pi^{-\frac{s}{2}}\sum_{k+}\left(\frac{k}{m'}\right)^{\frac{-s}{2}} K_{\frac{s}{2}}(2\pi m' k)\cos(2\pi k n + \delta)\right) \qquad (3)$$

which must be multiplied by $(\pi^{\frac{2s-1}{2}} / \Gamma\left(\frac{s}{2}\right))\,\Gamma\left(\frac{1-s}{2}\right)$ and inserted in (2) [see ref. 1 for details] to give the masses. One immediately realizes that the $M(n)$ ideally are periodic functions of n, where we have added a phase δ to allow slight changes in topology of the loops as compared to perfect circles. It is predicted that the mass of spin ½ baryons should be a cosine function of n, provided no other effects modify this parameter.

2) The inclusion of J=3/2 data in the analysis.

The data used in this analysis comes from ref[4] and is presented in Tables 1 and 2 (in the end of the paper).

Only the octet particles are spin J= ½ particles. One needs to calculate values of mass for the decuplet (J=3/2) particles in a spin ½ state, so that they can be included in the final analysis.

Firstly, in our previous publications the parameter *n* is defined for spin ½ particles through the equation[1]

$$n = (2c^2\alpha/e^3)\, \mu\, m. \tag{4}$$

which completely defines *n* from experimental data. In particular, one notices that *m* on the right side is proportional to the ratio n/μ , which contains the magnetic part of the mass. In principle, *n* and μ should be proportional to each other, since in the simplest cases flux inside a loop of radius *R* is given by $2\pi\mu/R$. The radius should not change with spin, and thus magnetic effects on mass given by the n/μ ratio should not change for excited spin states like J= 3/2 since both parameters change together. In fact, spin is an essentially kinetic effect rather than a magnetic one, and thus the increase in mass for higher spin can be assumed as fully kinetic in origin. To obtain suitable values for *n* in the decuplet from eq.(4) and spin ½ we then proceeded as follows. Masses for the hypothetical spin ½ states of decuplet barions are obtained simply by subtracting from the spin 3/2 masses the averaged kinetic excess over the octet masses, which is 244 MeV/c^2 . The results are called *transformed masses* m_t and are listed on Table 2. Then, values of n are obtained from eq (4) adopting the transformed masses to simulate spin ½ for decuplet particles, alongside the true measured values of μ for the decuplet. The Tables show that the obtained ratios n/μ are all around unit in dimensionless units for all Particles, which is the expected result. However, the Tables also show there are “jumps” in the values of n towards integer values, something typical of the presence of weak-links in the currents paths. Such weak-links are not considered in the perfect-ring model calculations adopted which resulted in the simple cosinusoidal expressions (1)-(3). For this reason we adopt the dimensionless μ in the analysis below, which might be considered the unperturbed version of the parameter n, and more adequate for comparison with the simple predictions of eq. (1)-(3).

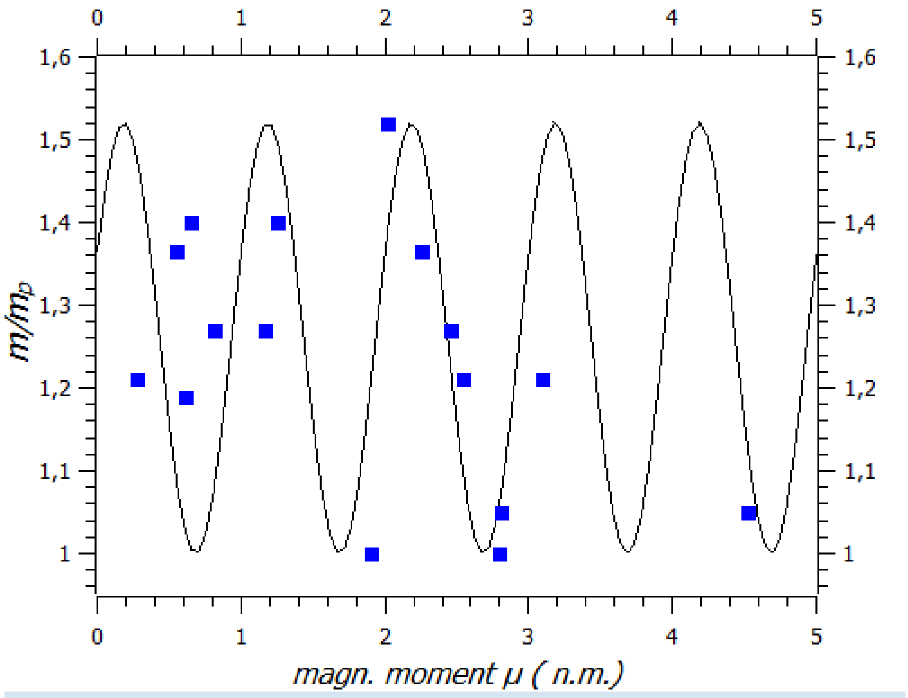

Figure 1: Plot of the ratio m/m_p from Tables 1 and 2(m_t used from Table 2 data) using the magnetic moments in the Tables in place of *n* in eq. (3). The curve is the plot of eqs.(2)- (3) with μ in place of *n*. One notices the very good fit obtained for 11 points above μ= 1.

3) Analysis and Conclusion.

Figure 1 above clearly displays the accuracy of eq. (3) for magnetic moments between 1 and 5 magnetons(taken as faithfully representing numbers of flux quanta unaffected by the effects of weak-links in the current path of a ring). The dimensionless parameters are $m' = m_p/m_0$, where $m_0 = 2\pi\hbar/cL$, and $u_0 = U_0/m_pc^2$. The fit gives $m' = 0.36$ and $u_0 =$ 2.5, which slightly correct numbers obtained in previous publications(a ½ correction factor is included here in the k=0 additive tern in (3) as compared to the expression in ref. [1]). This latter parameter corresponds to U_0= 2340 MeV, which is consistent with the peak position in the plot of cosmic rays protons flux analysed in previous work[2]. Below μ= 1 there is a scattering of data and the analysis loses precision, due to the uncertain fractions of a flux quantum contained in the ring.

In conclusion, this paper divulges for the first time the following results: *the masses of spin ½ baryons, in proton mass-units, are indeed a simple periodic function of their magnetic moments, in nuclear magneton-units*.[5] The applicability of electrodynamic methods in the analysis of baryons seems to have been clearly demonstrated by this analysis, including the existence of jumps in energy (rest mass) usually observed in superconductor circuits involving flux penetration through weal-links.

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Table 1: Baryon octet data(magnetic moments μ from ref. [4]). According to eq.(4) (gaussian units): n= 1.16x10^{47} μm.

	abs μ (n.m.)	μ(erg/G) x 10^{23}	m(Mev/c^2)	m(g) x 10^{24}	n eq.(4)
p	2.79	1.41	939	1.67	2.73
n	1.91	0.965	939	1.67	1.9
Σ^+	2.46	1.24	1189	2.12	3
Σ^0	0.82(theor.)	0.414	1192	2.12	1
Σ^-	1.16	0.586	1197	2.12	1.5
Ξ^0	1.25	0.631	1314	2.34	1.7
Ξ^-	0.65	0.328	1321	2.34	0.9
Λ	0.61	0.308	1116	1.98	0.7

Table 2: Baryon decuplet data (magn. moments μ from ref. [4]). The average mass difference between the decuplet and octet baryons, 244 Mev/c^2, is subtracted from the decuplet masses and the results m_t are placed in column 3 alongside the actual masses m and also in column 4. According to eq.(4) (gaussian units): n= 1.16x10^{47} μm_t.

	abs μ (n.m.)	μ(erg/G) x 10^{23}	m and $m_t = m$ - 244 (Mev/c^2)	m_t(g) x 10^{24}	n
Δ^{++}	4.52	2.28	1230/986	1.75	4.64
Δ^{+}, Δ^{-}	2.81,2.81	1.42	1234/990	1.75	2.9 , 2.9
Σ^{+}	3.09	1.56	1379/1135	2.02	3.65
Σ^{0}	0.27	0.136	1380/1136	2.02	0.32
Σ^{-}	2.54	1.28	1382/1138	2.02	3
Ξ^{0}	0.55	0.28	1525/1281	2.28	0.73
Ξ^{-}	2.25	1.14	1527/1283	2.28	3
Ω^{-}	2.02	1.02	1672/1428	2.54	3

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