A unified phenomenological description for the magnetodynamic origin of mass for leptons and for the complete baryon octet and decuplet

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RESUME. Les masses des leptons et des baryons sont décrites quantitativement en termes d'énergies magnétodynamiques considérant comme caractéristique fondamentale la quantification du flux magnétique à l'intérieur d'une "orbite" de mouvement « zitterbewegung » réalisée par chaque particule en raison de son équilibre avec le vide (comme proposé il y a plusieurs décennies par Barut, Jehle et Post). Comme une preuve supplémentaire de la solidité de la méthode, nous présentons un tracé de masse contre le moment magnétique dans lequel les données pour les particules de spin-3/2 (du décuplet) sont décalées des données pour le spin-1/2 (du octet) par le facteur exact 1,7 prédit à partir de la racine carrée du rapport entre leurs moments angulaires de spin

ABSTRACT. The masses of the leptons and baryons are shown to be quantitatively described in terms of magnetodynamic energies considering as a fundamental feature the quantization of magnetic flux inside a zitterbewegung motion "orbit" performed by each particle in consequence of its equilibrium with the vacuum background(as proposed decades ago by Barut, Jehle, and Post). As a further proof of the soundness of the method, we present a plot of mass against magnetic moment in which the data for the spin-3/2 decuplet particles are shifted from the data for the spin-1/2 octet by the exact 1.7 numerical factor predicted from the square root of the ratio between their spin angular momenta

1 Introduction

Several authors have reported the dependence of the rest masses of particles upon the inverse of the alpha constant. Barut was able to associate such behavior with magnetic self-energy effects due to « anomalous » magnetic moments in the case of leptons[1]. The present author has taken account of magnetic self-energy effects phenomenologically[2], in a way similar to that adopted by Post many years ago[3]. This paper presents the extension of the approach to the full baryon octet and decuplet, and the inverse dependence with alpha is obtained. The masses of all these particles are shown to be described in terms of magnetodynamic energies considering as a fundamental feature the quantization of magnetic flux inside a zitterbewegung motion "orbit" performed by each particle in consequence of its interaction with the vacuum background(Jehle[4] proposed flux quantization inside zitterbewegung orbits of particles as early as 1967).

Our previous work begins with the concept of gauge invariance and consequent flux quantization associated with the zitterbewegung intrinsic motion of fundamental particles. We then associated the magnetodynamic energy of the motion with the rest energy of a particle[2,3]. The main result of such phenomenological analysis was eq. (3) of [2]:

$$\frac{mR^2}{\mu} = \frac{nh}{2\pi ec} \qquad (1)$$

In this equation m is mass, R is a range for the vibrational-rotational intrinsic motion of the particle, μ is the magnetic moment, n is the number of magnetic flux quanta trapped inside the motion (the flux quantum given by hc/e). The objective is to investigate consistency between both sides of eq.(1). The model adopts experimental values for m and μ. For the nucleons R is taken from theoretical values for the extension of the charge density distributions of nucleons, calculated by Miller[5]. For the electron (and the muon) this parameter is assumed as equal to the Compton wavelength λ = ○/mc[6]. An agreement between model and experiment is obtained for that reduced group of particles after a criterion is chosen to calculate the values of n.

However, the extension of the model to other particles depends on the knowledge of the parameter R. In order to put the model to further test, in the present work we eliminate the explicit dependence of the model upon R. For the leptons the following well-known expression, consistent with the theory of zitterbewegung[6], is valid:

$$\mu = e\lambda/2 \qquad (2)$$

Here μ=μ_B is the magnetic moment in the case of the electron (μ_B is the Bohr magneton; if we replace the muon mass for the electron mass in the definition one obtains the "muonic" magneton). Stressing the point that the quivering motion, zitterbewegung, should be an intrinsic feature present in all particles, for the leptons and *for the baryons* considered in this work we will *assume* that in equation (2) $\lambda/\sqrt{2}$ can be directly replaced by *R*, so that *R* is eliminated from (1) in favor of μ (the scaling factor $1/\sqrt{2}$ to be applied here is rather arbitrary, but within the expected magnitude of 0.5 ~2) . It is clear that with this assumption the model associates mass to only two parameters, namely, to the number of flux quanta(which should be imposed by gauge invariance conditions), and to the inverse of the experimental magnetic moment.

Inserting the definition for *R* into eq. (1) and using the definition of the fine structure constant alpha, $\alpha = e^2/\circ c$, we can rewite eq. (1) in the form:

$$\frac{2c^2\alpha}{ne^3} m = \frac{1}{\mu} \tag{3}$$

It can immediately be noticed that if *n* and μ are proportional to each other, eq. (3) would produce an inverse dependence of *m* with the alpha constant, as reported in the literature. In the next sections eq. (3) is applied to the baryon octet and decuplet particles as well as to the leptons. Section 2 discusses the criteria for the choice of the parameters *n* to be used to fit the data. Section 3 presents the analysis of results and then the Conclusions in the last section.

2 Application to leptons and baryons

A.O.Barut [7,8] proposed that the short range strong interactions between the internal constituents of baryons would be magnetic in nature. The present model , whose main result is eq. (3), follows similar lines as the energies involved are magnetodynamic and related to self-fields produced by magnetic moments. However, a quantum-theoretical method for a precise determination of the values of *n*, the number of flux quanta in eq. (3), still has to be developed. In ref. [2] a tentative method of calculation based on the possibility of adding the contributions from each quark individually was proposed. However, the strict determination of these numbers would require the knowledge of the proper topological properties of each baryon and how to sum individual contributions from its constituents. Relativistic effects if relevant would certainly also have an effect on these numbers, which might even be half-integers. A previous attempt, in a model that also related particles to zitterbewegung was proposed by Jehle[4]. He associates particles representations with a topology of torus knots suitable to SU(n). Jehle obtains *n* from the combination of winding and whirling numbers of his proposed loopforms, which represent the quarks. Jehle´s work emphasizes the connection between magnetic flux and topology although not reaching quantitative confirmation from experiment.

On the other hand, there actually exists a semiclassical treatment (inspired on Barut´s ideas) that offers a way to deal with this issue[9]. Self-magnetic field effects would impose a cyclotron rotation to a particle, superimposed to its intrinsic(spin) rotation, and both effects taken together lead to the conclusion that *one fundamental magneton (either Bohr´s, or nuclear) produced by the self-field of a rotating elementary charge is related to exactly one quantum of magnetic flux trapped inside the orbit*[9]. From the standpoint of the present analysis this establishes a scaling criterion to convert the experimental values of the magnetic moment for particles (in nuclear or Bohr magneton units) into a number of flux quanta n. Ideally, this implies for the baryons that the ratio n/μ(n.m.)$\rightarrow$ 1. Consistently with what is expected from [9], in Table 1 we notice that the magnetic moments for the baryon *octet* in the last column are ordered in almost integer, small numbers of nuclear magnetons.

Table 1. Data utilized in Figure 1 for leptons and the octet of baryons. The magnetic moments are from ref. [10]. One needs to convert mass to grams, magnetic moments to erg/gauss (all CGS units).

Particle	**Rest mass(Mev/c^2)**	***n***	**Abs. Mag. mom.**
e	0.511	1	1 Bohr m.
muon	105.66	1	1 muonic m.
p	938.27	3	2.79 n.m.
n	939.56	2	1.91
Σ+	1189	2.5	2.46
Σ0	1192	1	~ 0.7 (theor.)
Σ–	1197	1.5	1.16
Ξ0	1314	1.5	1.25
Ξ–	1321	1	0.65
Λ	1116	0.61(for $n = \mu$)	0.61

Table 2. Data utilized in Figure 1 for the decuplet of baryons. Following [9], the values of *n* are chosen as the integer or half-integer numbers that follow as close as possible the sequence in the last column for the baryons(in n.m.), in order to fit theory to data. The magnetic moments are theoretical with exception of the first and last ones (from ref. [10]). One needs to convert mass to grams, magnetic moments to erg/gauss (all CGS units).

Particle	**Rest mass(Mev/c^2)**	***n***	**Abs. magnetic moment**
Δ++	1230	4.5	4.52 n.m.
Δ+	1234	2.5	2,81
Δ–	1237	2.5	2.81
Σ+	1379	2.5	3.09
Σ0	1380	0.25(for n~μ)	0.27
Σ–	1382	2.5	2.54
Ξ0	1525	0.5	0.55
Ξ–	1527	2	2.26
Ω–	1672	2	2.02

Considering that the magnetic moments should be proportional to the number of flux quanta trapped in the zitterbewegung motion, we take for n the integer (allowing also for half-integer) numbers which come closest to the observed magnetic moment in nuclear magneton units. The results for the leptons and baryon octet are displayed in Table 1 and we immediately notice that the ratio n/μ is approximately the same for all baryons. All the magnetic moment data for the baryons (octet and decuplet) come from [10]. Table 2 presents the data for the baryon decuplet particles. One notices also that there are (neutral) particles which have very small magnetic moments in nuclear magneton units (Λ, and Σ^0(J = 3/2), for instance) and are difficult to analyze with the simple assumption of taking integer or half-integer numbers of flux quanta. In this case we simply took the limit n/μ(n.m.)→ 1, following [9](cf. Tables).

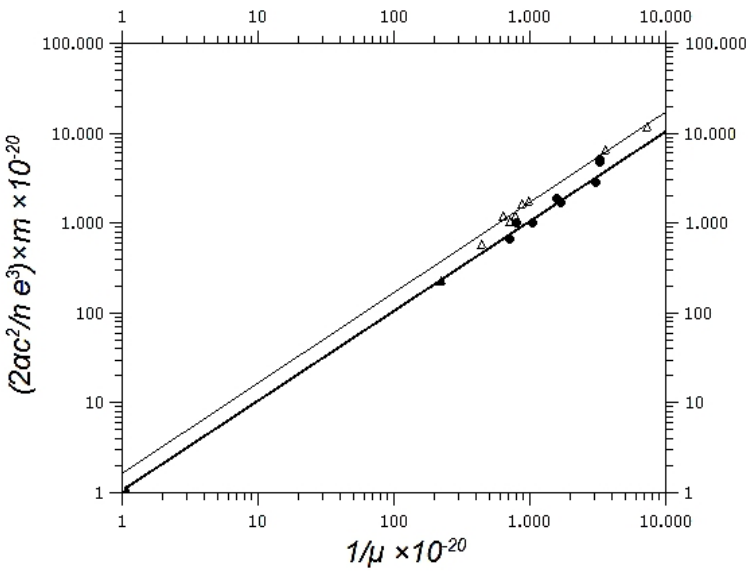
3 Analysis : the effect of spin on mass determination

Figure 1 shows the plot of eq.(3) and the lower straight solid line should be followed for a perfect agreement with theory. We notice that eq. (3) describes quite well the data available for leptons (solid triangles) and the octet of baryons (circles) with the values of *n* in Table 1. When we plot the data for the decuplet (open triangles) we notice a quite revealing distribution of the points, forming a second line parallel to the lower straight line shifted by a factor of 1.7. This result can be interpreted as a consequence of the influence of spin on the rest energies, as we now explain. The baryons of the decuplet are spin-3/2 particles. The spin angular momentum in the rest-frame of the center of mass of a particle is given by the product of the frequency of intrinsic rotation times the moment of inertia of the particle(such "classical" picture persists even in a detailed field-theoretical treatment of the zitterbewegung rotation by Barut and Bracken; see [6]). In this case the frequency is the zitterbewegung rotation frequency $2mc^2/\circ$ which is proportional to mass, while the moment of inertia is proportional to the mass and to R^2. Therefore, if one picks a point on each line at the same value of the abscissa μ, and thus from eq.(2) the same value for R, the ratio between the values of m^2 for the octet and the decuplet particles is 1/3 in view of the ratio between the spin angular momentum values(note that linear variations of m^2 as a function of the angular momentum of particles have been reported in the past, including the possible association of this fact with zitterbewegung, which has been proposed; see[11]). Since *n* should also be the same for same values of μ we immediately conclude that the (ideal) theoretical ratio between the ordinates (m/n) of the two points in the double-logarithmic plot is $\sqrt{3}=1.73$, with the octet line below the decuplet line. The experimental data in the Figure tend to follow such behavior with small deviations related to details not included in the simple analysis above. For instance, note that the ratio between the mass of the decuplet Ω particle and the mass of the neutron (n) is 1.77, which is quite close to 1.73. This is fully consistent with the fact that they have essentially the same magnetic moments (cf. Tables).

Detailed investigations have been carried out to gather and interpret experimental data for mesons and baryons[11-14]. A dependence of mass with the inverse powers of α has been reported[12,14]. We see from eq. (3) and Figure 1 that an inverse relation with α indeed is part of our results, since following [9] the ratio n/μ is essentially the same for all baryons. In particular, the analysis in ref. [14] might be reproduced if the ratio n/μ in (3) is made part of the *free* parameter N in ref. [14].

To sum up, it would be important to formally account for the influence of Symmetry(introduced here through the rather straightforward imposition of flux quantization and gauge invariance in their simplest forms) in a way consistent with the SU(n) nature of baryons. A proper rigorous treatment following for instance the lines proposed by Jehle[4] might definitely impose the values for *n*, as well as their association with the magnetic moment data (which should anyway deviate little from direct propostionality [9]).

Figure 1. Plot of eq.(3) with data from the Tables. Solid triangles are leptons, solid circles represent the baryon octet, and open triangles the decuplet. The upper line is a factor of 1.7 above the lower line, which corresponds to full agreement with eq.(3).



4 Conclusions

We have applied the previously developed magnetic energy model for the description of mass [2,3] to the leptons and to the entire baryons octet and decuplet. The theoretical expression eq. (3) fits well the spin-1/2 octet particles and leptons. The shift between the plots for the decuplet as compared to the octet of baryons can be quantitatively attributed to the greater spin of the decuplet(cf. [11]). A contribution of the present work is the explicit introduction of flux quantization in the description of mass for hadrons(something previously done for the electron only), which leads to an *overall connection* between several pieces of empirically organized sets of data for baryons, accumulated along the years[11-14] In addition, the analysis in this paper reinforces the perception that symmetry effects [4] determine the fine details of the problem of mass determination through their influence on the parameter *n* (here determined by simple requirements related to gauge invariance of particles wave-functions[2]), and thus the consideration of magnetic fields (due to anomalous moment terms[1,2]) in the subnuclear scale is essential(since they are related to Symmetry and produce the magnetic flux) , as proposed by Barut, Post, and Jehle, among others**.** Further work is underway and concentrates on the improvement of the evaluation method of the parameters *n*.

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