A unified description for the magnetic origin of mass for leptons and for the complete baryon octet and decuplet.

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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 interaction 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 numerical factor predicted from the square root of the ratio between their spin angular momenta.

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 in the case of leptons[1]. The present author has taken account of magnetic 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]:

$$\frac{mR^2}{\mu} = \frac{nh}{2\pi ec} \tag{1}$$

In this equation *m* is mass, *R* is the range of 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(admitted as given by the expression *hc/e*). The parameter *R* can also be considered as the representative classical size of the current loop that would produce magnetic properties of a particle. The model in [2] adopts experimental values for *m* and μ. For the nucleons *R* was given by theoretical values calculated by Miller[5], and for the electron (and the muon) this parameter was assumed as equal to the Compton wavelength $\lambda = \hbar/mc$[6]. Good agreement between model and experiment was obtained for that reduced group of particles.

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 decided to simply try and eliminate the explicit dependence of the model upon *R*. In particular, the magnetic moment μ is available for the full baryon octet and decuplet particles. For the leptons the following expression, consistent with the theory of zitterbewegung[6], is known to be valid:

$$\mu = e\lambda/2 \tag{2}$$

In the case of the electron $\mu = \mu_B$ (μ_B is the Bohr magneton). The same expression applies to the muon, and we call these the " leptonic magnetons". Stressing the point that the quivering motion, zitterbewegung, is an intrinsic feature present in all particles, for the leptons and for the baryons considered in this work we will *assume* that in eq.(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 imposed by gauge invariance conditions and the charges of the constituents inside the baryons, and to the inverse of the experimental magnetic moment.

Inserting the definition for *R* into (1) and using the definition of the fine structure constant alpha, $\alpha = e^2/\hbar c$, we can rewite (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 section eq. (3) is applied to 19 particles with quantitative success.

Application to Leptons and Baryons

A.O.Barut [7,8] proposed an alternative theory for the inner constitution of baryons and mesons, in which the basic pieces would be the individual, *stable* unit-charge particles, namely the proton , the electron (and in addition, the neutrino). After so many years, evidence has accumulated in support of the quark model at least as far as the inner structure of baryons is concerned. However the fact that the decay products of baryons are unit-charge particles is an important result which is explored in the analysis that follows. Barut proposed also that the short range strong interactions between such internal constituents would be magnetic in nature. Although we do not develop such proposal in detail, the present model , whose main result is eq. (3), follows similar lines as the energies involved are magnetodynamic. The application of eq. (3) requires a quantum-theoretical method for a precise determination of the values of *n*, the number of flux quanta, which is not available. 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. Topological details would certainly 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], associating particles to the topology of torus knots, without definitive conclusions.

However, there actually exists a semiclassical treatment that offers a way to deal with this issue[9]. Self-magnetic field effects produced by the intrinsic (spin) motion of a particle would impose also a simultaneous cyclotron rotation. Both effects taken together produce magnetic flux across the orbit, which leads to the conclusion that *one fundamental magneton (either Bohr´s, or leptonic, or nuclear) of magnetic moment produced by an elementary unit of charge is related to exactly one quantum of magnetic flux trapped inside the orbit*[9]. The derivation is valid for unit-charge leptons and the proton. That is, considering that *flux conservation* is followed in the decay of baryons, even in the absence of knowledge about how to impose flux quantization to quarks one might concentrate only on the unit- charged final products of the decay. 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 leptonic magneton units) into a number of flux quanta *n*. Ideally, this implies for the baryons that the ratio $n/\mu(\text{n.m.}) \rightarrow 1$. 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. 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 or half-integer number which is closest to the observed magnetic moment in nuclear magneton units. The results for the leptons and baryon octet are displayed in Table 1. All the magnetic moment data for the baryons (octet and decuplet) come from [10]. Table 2 presents the data for the baryon decuplet particles.

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 observe that eq. (3) describes very well the data available for leptons (solid triangles) and the octet of baryons (circles) with the values of n in Table 1. Relativistic corrections are apparently very similar (or absent)for all these spin-1/2 particles. 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 is a very important result, which gives further proof of the soundness of the present ideas, and the influence of spin on this analysis.

The following heuristic interpretation seems applicable in this case. The baryons of the decuplet are spin-3/2 particles. The spin angular momentum is given by the product of the frequency of rotation times the moment of inertia of the particle(such simple picture persists even in a detailed field-theoretical treatment of the angular momentum problem in the internal rest frame of reference of an electron; see [6]). In this case the frequency is the zitterbewegung rotation frequency $2mc^2/\hbar$ which is proportional to mass, while the moment of inertia is proportional to the mass and to the square of the mass (energy) distribution range ρ^2. Therefore, if one picks a point on each line of Figure 1 at the same value of the abscissa μ, 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, assuming that ρ should be about the same since it is associated with the magnetic energy density spatial distribution due to the zitterbewegung charge motion. Since n should also be the same for same values of μ we immediately conclude that the theoretical ratio between the ordinates (m/n) of these two points is $\sqrt{3}=1.73$, with the octet line below the decuplet line, shifted by the logarithm of this number, a behavior that is generally followed by the experimental data in the Figure. The pair of real particles in Figure 1 which comes closer to strictly following this condition is that formed by the neutron(n) and the decuplet hyperon Ω^- (cf. data on the Tables and the Figure). They have practically the same magnetic moments and their rest masses differ by 77%, which is very close to the theoretical value 73%. The agreement is poorer (points below the upper line)for the most unstable decuplet particles (meanlives of about 10^{-24} sec.)since the values of ρ should vary markedly when compared to the much more "stable" octet particles(meanlives of 10^{-21} sec. or longer). Miller´s calculations [5] display the full *superposition* of the charge density of quarks – and thus smallest possible ρ – in stable nucleons. It is thus expected that unstable particles are spread in larger regions since their constituents would not fully superimpose during their extremely short lives, and thus the mass of unstable particles can lay below the upper line in the Figure since the angular momentum is compensated by the increase in ρ.

It must be pointed out that most of the data for the magnetic moments for the decuplet are theoretical and vary according to the parameters adopted in the calculations [10]. The data on the Tables are those for the string tension parameter[10] value 0.09 Gev^2, which the authors claim produces also better estimates for mass (from QED calculations). As far as the present analysis is concerned, a single adjustable parameter is necessary, which can be considered as the factor relating R and λ in eq. (2).

The influence of topology(introduced through the concepts of flux quantization and gauge invariance) is evident in view of the importance of the sequence of values for *n* in the Tables, and their association with the actual magnetic moment data, which can only be interpreted in such geometrical terms. The utilization in this work of a direct proportionality between μ and *n* [9] corresponds to ignoring any deviations from euclidean geometry and even relativistic corrections. A slightly different set of values for *n* might easily be generated by taking as starting point an analogy with simplified theoretical calculations of the magnetic moments for baryons. Such calculations are available for instance in the book by D. Griffiths, Introduction to Elementary Particles, Wiley-VCH, Weinheim(2nd edition, 2008). Values for *n* might be obtained by replacing the magnetic flux of each quark for the corresponding magnetic moments in the baryon magnetic moments expressions, which are consistent with the algebra of SU(3)(cf. Griffiths, p.189 and ff.).

Detailed investigations have been carried out to gather and interpret experimental data for mesons and baryons[11-13]. A dependence of mass with the inverse powers of α has been reported. 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. The differences are theoretically related to the particular representations of SU(3) to which each of them belong. In particular, eq. (3) applied to the nucleons produces the same expression for mass as that obtained by MacGregor, which writes it as a function of the electron mass and the alpha constant only[11]. The fully empirical analysis in ref. [13] might probably be reproduced if the ratio n/μ in (3) is made part of their *free* parameter N. Further work is clearly necessary to test the applicability of this model to the large amount of data treated in these references.

Conclusions

We have applied the previously developed magnetic energy model for the origin of particles [2] to the entire baryons octet and decuplet. The theoretical expression eq. (3) fits well the 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. The analysis in this paper reinforces the perception that geometrical or topological effects dominate the problem of mass determination, and thus the consideration of magnetic effects in the subnuclear scale is essential, as proposed by Barut, and Jehle, among others.

References

1. A.O.Barut, Phys.Lett. **73B**, 310(1978); Phys.Rev.Lett. **42**,1251 (1979).
2. O.F.Schilling, vixra: 1511.0005 (a previous version appeared in J.Mod.Phys. (scirp.org)**4**(9), 1189(2013)).
3. E.J.Post, Phys.Lett. **119A**, 47(1986).
4. H. Jehle, Phys. Rev. **D11**, 2147 (1975), and his previous work cited therein.
5. G.A.Miller, Phys. Rev. Lett**. 99**, 112001 (2007).

6. A.O.Barut and J.A.Bracken, Phys. Rev. **D23**, 2454 (1981).
7. A.O.Barut, Stable particles as building blocks of matter, ICTP publication IC/79/40 (1979).
8. A.O.Barut, Leptons as quarks, Universite de Geneve(preprint), (1978).
9. M.Saglam and G. Sahin, Int.J.Mod.Phys. **B23**, 4977 (2009).
10. Y.A. Simonov, J. A.Tjon and J. Weda, Phys.Rev. **D65**, 094013(2002).
11. M.H. MacGregor, The Power of Alpha, World Scientific, Singapore(2007). See also arxiv.org/hep-ph/0607233 (2006).
12. P. Palazzi, www.particlez.org/p3a/
13. K.O.Greulich, J.Mod.Phys.(scirp.org) **1**(5), 300(2010).

Table 1: Data utilized in Figure 1 for leptons and the octet 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 order to fit theory to data. The magnetic moments are from ref. [10]. A leptonic magneton (l.m.) refers either to the Bohr magneton for the electron or to the same formula with the muon mass replacing the electron mass. All magnetons refer to unit(elementary)-charge particles. One needs to convert mass to grams, magnetic moments to erg/gauss (all CGS units).

part	Rest energy(MeV)	n	(Abs)Magnetic moment(n.m. or l.m.)
e	0.511	1	1
muon	105.66	1	1
p	938.27	3	2.79
n	939.56	2	1.91
$\Sigma+$	1189	2.5	2.46
$\Sigma 0$	1192	1	0.85 (theor.)
$\Sigma-$	1197	1.5	1.16
$\Xi 0$	1314	1.5	1.25
$\Xi-$	1321	1	0.65
Λ	1116	0.5	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, in order to fit theory to data. The magnetic moments are from ref. [10](only the first and last are experimental results; the others are theoretical). The Δ^0 particle is not included since its (theoretical) moment is zero. One needs to convert mass to grams, magnetic moments to erg/gauss (all CGS units).

part	Rest energy(MeV)	n	(Abs)Magnetic moment(n.m.)
Δ++	1230	4	4.52
Δ+	1234	3	2.81
Δ–	1237	3	2.81
Σ +	1379	3	3.09
Σ 0	1380	0.25	0.27
Σ –	1382	2.5	2.54
Ξ 0	1525	0.5	0.55
Ξ –	1527	2	2.26
Ω –	1672	2	2.02

Figure 1: Plot of eq. (3). 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 perfect agreement with eq. (3). This shift is attributed to the ratio 3 between the spin of the decuplet and octet particles, which shifts the scales for each plot by a factor of √3 (see text).