A Preon Model from Manasson's Theory

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V. Manasson has applied dissipative chaos theory to particle physics, deriving a simple relation between the fine structure constant and Feigenbaum delta constant. It is presented a preon model based on Manasson's theory. The model is intended as a naive toy one, as it makes use of unjustified assumptions, as e.g. the possibility of the existence of neither fermionic nor bosonic particles in 3+1 spacetime.
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In [1,2] V. A. Manasson developed a model of the relation of chaos theory with particle physics. A very interesting result presented by Manasson is a formula relating the fine structure constant α with Feigenbaum constant δ:

$$\alpha = (2\pi\delta^2)^{-1} \tag{1}$$

Figure 8(d) at page 8 in [1] is particulary inspiring: the image depicts a hierarchical relation, guided by the period doubling bifurcation diagram, in which the nodes of the tree are labeled with particles: in the first bifurcation the spin-2 graviton transforms to two spin-1 photons, acquiring polarization; the next bifurcation is from photon to spin-1/2 electron-positron, acquiring electric charge.

We consider the possibility that also the next level of this hierarchy could be physically meaningful. The hypothetical particle that "lives" at this level is assumed to have spin 1/4: it needs to rotate 8π to resume its initial state.

Fractional spin has been observed in anyons [3], particles which exist only in 2+1 spacetime.
It is an established assumption that in 3+1 spacetime particles obey only bosonic or fermionic behaviour. The model proposed in this paper is a naive toy one, as it assumes that a particle with fractional spin can be used as a building block (preon [4]) for the majority of the known particles. Also in four dimension, anyway, the search for exotic statistics is an active field [5].

Properties of the proposed particle

We call our spin 1/4 particle “mark”.

In the literature one can find similar objects under the names of “semions”, “plektons”, “cyons” or “half fermions”.

We assume that a mark possesses three quantum numbers, and that every quantum number can assume a value of +1 or -1.

The first quantum number is spin, the second is electric charge, the third is a precolor charge.

We conjecture that at every step of the period doubling bifurcation the value of a quantum number is halved.

From this assumption we infer that the absolute value of the electric charge of a mark is $e/2$.

We denote a mark in this way: M1(x, y, z), with $x, y, z \in \{-1, 1\}$.

Marks can group together, always in even number.

The notation Mn(x, y, z) means a group of n marks, with $n \in \{2, 4, 6, ...\}$, $x, y, z \in \{..., -4, -2, 0, 2, 4, ...\}$.

The naive idea is to sum algebraically the quantum numbers. In this way two marks with parallel spins mimic a fermion (spin 1/2), with antiparallel spins mimic a boson (spin 0). Four marks with all parallel spins mimic a boson too (spin 1).

We are aware that the use of this procedure would need some justification: for example, in [6] it is stated: "[...] This implies that vortices with the basic flux unit $\Phi = 2\pi/e$ will carry charge $e/2$. Furthermore, whereas ordinary composites with these values of the flux and charge would be fermions, according to our previous discussion, these objects have statistical phase $\exp(i\pi/2)$, i.e., they are "half-fermions". This result is consistent with a generalized spin-statistics connection, given Paranjape's calculation of induced angular momentum $L = 1/4$ for the vortex. It is also worth noting that, while these objects then have phase and spin half that of an ordinary fermion, combining two of them together makes a boson, since spin and phase go as the square of the number of units."

Anyway, being the our only a toy model, we proceed further with the analysis of its characteristics.

Looking for a Pauli-like principle

The configuration M2(±2, ±2, 0) is forbidden because it produces an "annihilation": for example, in the period doubling bifurcation tree, M1(1, 1, 1) cannot couple with M1(1, 1, -1) because either are "sons" of a spin-up positron. In other words, they belong to the same branch of the bifurcation tree.

What about M2(±2, ±2, ±2)? It is not clear to us if this is a forbidden configuration: it seems so, because all the three quantum numbers have the same value in the pair.

Now let us consider M2(0, ±2, ±2): if one exchange the marks the overall wave function will be:

$$|\psi_1\psi_2\rangle = \exp(i\pi/2)|\psi_2\psi_1\rangle = i|\psi_2\psi_1\rangle \qquad (2)$$

Trying to escape this unphysical situation, we propose to adopt the following formula:

$$|\psi_1\psi_2\rangle = \exp(\mu i\pi/2)|\psi_2\psi_1\rangle \qquad (3)$$

where the coefficient μ is the number of different quantum numbers of the two marks.

For example, in M2(2, 0, 0) electric and precolor charges are different and the coefficient μ is 2:

$$|\psi_1\psi_2\rangle = \exp(2i\pi/2)|\psi_2\psi_1\rangle = -|\psi_2\psi_1\rangle \qquad (4)$$

recovering fermionic behaviour.

This behaviour is like sending, in the complex plain, the point (1, −1) to (1, 1) multiplying by i (one different quantum number), or to (−1, 1) multiplying by −1 (two different quantum numbers).

This concept could have some analogy with Schur-Wilczek statistics [7].

It seems also that no more than four marks can occupy the same energetic level, in analogy with pair of electrons in atoms [8].

We note that M2(2, 0, 0) has the characteristics of a neutrino: spin 1/2, neutral, colorless.

Mac Gregor hierarchy of masses

Malcom Mac Gregor and other authors, following Nambu [9], have discovered scaling relations between the masses of elementary particles, where the coefficient of the scaling has an integer relation with the fine structure constant α.

In particular Mac Gregor defines "a boson mass quantum $m_b = m_e/\alpha = 70.025$ MeV and a fermion mass quantum $m_f = (3/2)\ m_b = 105.038$ MeV", where m_e is the electron mass. "m_f is identified with the muon".

We conjecture that the mass of a mark is $m_e/4\alpha = 17.5$ MeV.

The **muon** could be composed as M6(2, −2, 0), recovering from $17.5 \cdot 6 = 105$ MeV the muon mass roughly.

Following Barut's formula [10] we can also hypothesize that the muon has a structure M6(0, 0, 0) plus an electron, which gives spin and charge to the ensemble, with a better agreement to experimental values.

For a charged **pion**, M8(0, ±2, 0) could mimic its structure: $17.5 \cdot 8 = 140$ MeV, near the 139.57 MeV experimental value.

The **proton** and the **neutron** have roughly a mass of 54 marks [11]. Naturally follows that **up** and **down** quarks could be composed of 18 marks.

Supermarks

MacGregor observes that $m_t = 18 m_e/\alpha^2$, where m_t is the top quark mass. Besides, for the W boson $m_W = (17/2) m_e/\alpha^2$ and for the Z boson $m_Z = (19/2) m_e/\alpha^2$, almost exactly.

From these observations we are led to consider the next level of the spin hierarchy, namely, a particle with spin 1/8.

We call this particle "supermark", and we denote it with SM1(x, y, z, w), with x, y, z, w $\in$ {−1, 1}.

Because of the relation with W and Z, we call the fourth quantum number "weak charge".

In analogy with the conjecture that no more than four marks can occupy the same energetic level, we hypothesize that eight supermarks fill an energetic level.

Following our proposed value for the mass of a mark ($m_e/4\alpha$), we multiply again for $1/4\alpha$, obtaining for the mass of a supermark a value of $m_e/16\alpha^2 = 586.5$ MeV.

Then we obtain the number of supermarks involved in the composition of the following particles: for the **top** quark 288, for the **W** boson 136 and for the **Z** boson 152.

We end this section noting that SM4(4, 0, 0, x), as M2(2, 0, 0), has the characteristics of a neutrino. Because neutrinos feel the weak force, the "weak charge" x generally is not zero. If such a cluster of 4 supermarks could model a neutrino, it is not clear why they lose almost all of their masses. We could think to a sort of "quasi-annihilation", happening when the supermarks in the cluster belong not to the same branch of the bifurcation tree (this should produce a true annihilation), but to "near" branches.

Speculations on possible relations between algebras and forces

The following conjectures has a character mainly intuitive, so we shall not develop very deeply the introduced topics.

We speculate that the hierarchy of period doubling bifurcations could be connected with normed division algebras, and also with sedenions, or with complexified octonions (bioctonions) [12]:

- at the first level graviton-gravity is connected with the reals
- then photon-electromagnetism with complex numbers
- at the third level we find the electron-positron: in our model this is the only true fermion and is connected with quaternions
- marks bosonically grouped are related with the strong interaction and with octonions
- supermarks bosonically grouped are related with the weak interaction and with sedenions, or with another 16-dim algebra

We list two observations which can give a minimum of support to our conjectured classification:

in [13]: "spin-1/2 particles in nonrelativistic quantum mechanics are naturally quaternionic if we take time reversal into account!"

in [14]: "The symmetry group of the strong interactions can be more simply expressed in octonionic terms than complex or quaternionic."

We can find a possible application of this classification: in [15] it is claimed that "one way to understand octonions is as the "second coming" of the reals". Considering our classification, this could correspond to a relation between gravity and the strong force. In the literature concepts as "strong gravity" [16] and "gravistrong interaction" [17] are proposed.

The concept of "second coming" perhaps applies also to complex numbers and sedenions. The roots of electroweak unification could have their origin from this concept.

Moreover, “Gunaydin and Gursey established a relationship between SU(3)–color quark symmetry and the algebraic structure of the fields constructed on the octonions.” [18] We note that 3 is the number of color charges and 2^3 is the dimension of the octonions. A 2^4-dimensional algebra could be related with weak hypercharge and weak isospin, seen as a sort of 4-valued charge. Being 4 even and being electric charge 2-valued, this could explain the unification of the weak interaction with electromagnetism. Also the analogy beetween gravity and strong force could be related to the oddity of the “mass charge” (1-valued) and of the color charge (3-valued).

Anyway, in our model the precolor charge is 2-valued. A possible explanation of how to obtain “triality from duality” is that marks arrange themselves in such a way that the permitted configurations mimic the behaviour of quarks. The way marks arrange themselves could be dictated by the octonionic structure of the related algebra.

Majoranons

In [19] there is an historical account about the origin and the development of parastatistics, starting from the work of Giovanni Gentile Jr in 1940 [20]. In [21] we can find the definition of a kind of particles named gentileons, different from boson and fermions.

“In 1932 Ettore Majorana proposed an infinite-component relativistic wave equation for particles of arbitrary integer and half-integer spin.” [22]

Majorana pioneered the introduction of the concept of arbitrary spin. We would call the preonic particles of spin 1/4 and 1/8 treated in this article *majoranons*, in honour of Ettore Majorana.

Conclusions

V. A. Manasson made a peculiar application of nonlinear dynamical systems theory to particle physics. Following Manasson's theory, we are led to formulate a model with preons with a neither bosonic nor fermionic behaviour. In 3+1 spacetime this behaviour usually is reputed impossible. The main idea of this work is to suppose that such a behaviour is possible. From this assumption we develop a toy model that offers an explanation to the phenomenon of mass quantization of particles. The model is based on a cascade of bifurcations of quantum numbers and on a hierarchy of elementary particles with fractional spin. We end with speculations inspired by the analogy between the period doubling bifurcation tree and the dimensional doubling of the principal division algebras.

Acknowledgment

I express my admiration and thanks to Vladimir A. Manasson for his inspirational theory.

Dedication

To Marilinda, my love, my source of inspiration, for her patience, support and continuos dedication to our family. Without her this work could not have been done.

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