Constraints on gauge boson compositeness from discrete time gauge boson spin polarization precession

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ABSTRACT. By studying the two preon composite structure of the electroweak gauge bosons we arrive at criteria sufficient to place constraints on the preon charges and masses and gauge boson electric dipole moments using discrete time spin polarization precession.

RÉSUMÉ. *Si l'on étudie la structure des bosons de jauge électrofaible, composée de deux préons, on arrive à des critères suffisants pour imposer des contraintes sur les charges et les masses du préon et sur les moments dipolaires électriques du boson de jauge en utilisant une précession à temps discret de la polarisation du spin.*

1. Introduction.

The present frontier of physics suggests that there are three fundamental areas that require further investigation to ascertain the true structural features of the underlying theory. The first involves a deeper understanding of particle theory since the present structure of the Standard Model suggests an incomplete and cosmetic understanding of the chirality of the weak interactions, a poorly understood picture of the Higgs sector with its associated symmetry breaking properties and lastly a fragmented understanding of the generation structure of the quarks and leptons [1,2]. Compositeness [3], grand-unification [4], technicolor [5] and perhaps superstrings[6] offer us directions in which the nature of the true theory may emerge. The second area of exploration involves the problem of gravitation and its possible emergence from possibly a supergravity theory in higher dimensions [7], a superstring theory [6] or possibly from a discrete pre-geometric theory of space and time[8]. The third fundamental area that borders on the frontier searches for the fundamental origin of quantum phenomena and the associated properties of non-locality and incompleteness [9,10]. In search of a more primitive origin to quantum phenomena and building upon previous suggestions by Wheeler [11], Finkelstein [12], Recami [13], Caldirola [14,15] and others [16,17] we have considered a discrete time quantum theory [18;19;20;21;22] and the modifications it leaves on presently measurable phenomena. The fundamental roots of such a theory emerge from the belief that particles have a fundamental individuality prior to the birth of Minkowski space-time and even after our averaged out sense of space-time is "born" the particles frame may still fluctuate from the average, thus to express this fact or "fundamental uncertainty principle in time" a discrete time difference appears in the equations of motion. In a recent work we have applied this idea to gauge boson spin-polarization precession which proved to be a probe to both the composite structure of gauge bosons as well as a probe to discrete time effects [23]. A possible probe to gauge boson structure within the present structure of particle theory is found by studying deviations of the magnetic moment and electric quadripole moments of the w^+, w^- from standard model values [24,25], also the appearance of an electric dipole moment would be a signal of composite gauge boson structure. In what follows we study the constraints on composite gauge boson structure implied by discrete time spin polarization precession as well as the signatures in spin polarization precession generated by a gauge boson electric dipole moment. Thus, the analysis represents a probe to both discrete time effects and composite gauge boson structure with more specific signatures than that discussed in [23].

2. Composite gauge boson strucure and discrete time quantum theory.

We consider a w^- gauge boson to be composed of two preons with charges $-e_1$, $-e_2$, the hamiltonian in a z component magnetic field $B_z = B$ and electric field $E_x = E$ is

$$\begin{aligned} H =& M_0C^2 + \frac{P_1^2}{2m_1} + \frac{P_2^2}{2m_2} + \frac{e_1}{m_1}S_{z_1}B + \frac{e_2}{m_2}S_{z_2}B \\ &+ P(S_{x_1} + S_{x_2})E + g\vec{S}_1.\vec{S}_2 \end{aligned} \tag{2.1}$$

Here M_0C^2 = rest mass energy, $g\vec{S}_1.\vec{S}_2$ = spin-spin coupling.

We employ the non-relativistic approximation since preons have heavy masses m_1, m_2, the term containing B represents the magnetic dipole interaction (g=2 for erach preon) and the term containing E is the electric dipole interaction with the gauge boson admitting an electric dipole movement (P) in units of $\hbar$. If we first consider the case $P = 0$ and the preons are confined to an infinite potential well from 0 to L we have in the discrete time quantum formalism [23].

$$\left[M_0C^2 - \frac{\hbar^2}{2m_1}\frac{\partial^2}{\partial x_1^2} - \frac{\hbar^2}{2m_2}\frac{\partial^2}{\partial x_2^2} + \frac{e_1}{m_1}S_{z_1}B + \frac{e_2}{m_2}S_{z_2}B + g\overrightarrow{S}_1.\overrightarrow{S}_2\right]\Psi$$
$$= i\hbar\left[\frac{\Psi\left(t+\frac{\tau}{2}\right) - \Psi\left(t-\frac{\tau}{2}\right)}{\tau}\right] \tag{2.2}$$

$\tau =$ discrete time interval.

We consider the separable function

$$\Psi = U(x_1, x_2)\left[a_1\alpha\alpha + a_2\beta\beta + a_3\frac{(\alpha\beta+\beta\alpha)}{\sqrt{2}}\right]T(t) \tag{2.3}$$

($\alpha\alpha = \alpha(1)\alpha(2)$, $\alpha =$ spin up; $\beta =$ spin down function, $\alpha\beta = \alpha(1)\beta(2)$, etc.) giving

$$\left(-\frac{\hbar^2}{2m_1}\frac{\partial^2}{\partial x_1^2} - \frac{\hbar^2}{2m_2}\frac{\partial^2}{\partial x_2^2} + M_0C^2\right)U(x_1, x_2) = E_1U(x_1, x_2) \tag{2.4}$$

$$\left(\frac{e_1}{m_1}S_{z_1}B + \frac{e_2}{m_2}S_{z_2}B + g\overrightarrow{S}_1.\overrightarrow{S}_2\right)\left[a_1\alpha\alpha + a_2\beta\beta + a_3\left(\frac{\alpha\beta+\beta\alpha}{\sqrt{2}}\right)\right]$$
$$= E_2\left[a_1\alpha\alpha + a_2\beta\beta + a_3\left(\frac{\alpha\beta+\beta\alpha)}{\sqrt{2}}\right)\right] \tag{2.5}$$

$$(E_1 + E_2)T(t) = i\hbar\left[\frac{T\left(t+\frac{\tau}{2}\right) - T\left(t-\frac{\tau}{2}\right)}{\tau}\right] \tag{2.6}$$

For the spatial solution we have

$$E_1 = M_0C^2 + \frac{n_1^2h^2}{8m_1L^2} + \frac{n_2^2h^2}{8m_2L^2} \tag{2.7}$$

$$U(x_1,x_2)=\frac{1}{\sqrt{2}}\left[\frac{2}{L}\sin\frac{n_1\pi x_1}{L}\sin\frac{n_2\pi x_2}{L}-\frac{2}{L}\sin\frac{n_2\pi x_1}{L}\sin\frac{n_1\pi x_2}{L}\right] \tag{2.8}$$

where we have constructed an antisymmetric spatial state. For the spin state we have

$$\begin{aligned}&\left(\frac{e_1}{m_1}+\frac{e_2}{m_2}\right)\frac{\hbar}{2}B\alpha\alpha a_1-\left(\frac{e_1}{m_2}+\frac{e_2}{m_2}\right)\frac{\hbar}{2}B\beta\beta a_2\\&+B\left(\frac{e_1}{m_1}-\frac{e_2}{m_2}\right)\left(\frac{\alpha\beta-\beta\alpha}{\sqrt{2}}\right)\frac{\hbar}{2}a_3\\&+\frac{g\hbar^2}{4}\left[a_1\alpha\alpha+a_2\beta\beta+a_3\left(\frac{\alpha\beta+\beta\alpha}{\sqrt{2}}\right)\right]\\&=E_2\left[a_1\alpha\alpha+a_2\beta\beta+a_3\left(\frac{\alpha\beta+\beta\alpha}{\sqrt{2}}\right)\right]\end{aligned} \tag{2.9}$$

The eigenstates are for the spin component

$$E_{2+}=\left(\frac{e_1}{m_1}+\frac{e_2}{m_2}\right)\frac{\hbar B}{2}+\frac{g\hbar^2}{4},\quad \Psi_+=\begin{pmatrix}1\\0\\0\end{pmatrix},\quad \Psi_+=\alpha\alpha \tag{2.10}$$

$$E_{2-}=-\left(\frac{e_1}{m_1}+\frac{e_2}{m_2}\right)\frac{\hbar B}{2}+\frac{g\hbar^2}{4},\quad \Psi_-=\begin{pmatrix}0\\0\\1\end{pmatrix},\quad \Psi_-=\beta\beta \tag{2.11}$$

$$E_{20}=\frac{g\hbar^2}{4},\quad \Psi_0=\begin{pmatrix}0\\1\\0\end{pmatrix},\quad \Psi_0=\frac{\alpha\beta+\beta\alpha}{\sqrt{2}} \tag{2.12}$$

providing $e_1/m_1=e_2/m_2$. Thus in order to generate the three eigenstates we must have the constraint $e_1/m_1=e_2/m_2$ for the preons. The solution to Eq.(2.6) is

$$T(t)=Ce^{-\frac{2}{\tau}\left(\sin^{-1}\frac{(E_1+E_2)\tau}{2\hbar}\right)it} \tag{2.13}$$

If we study gauge boson spin polarization and insist that

$$\langle S_x\rangle_{t=0}=\langle S_{x_1}+S_{x_2}\rangle_{t=0}=\hbar$$

we have for the initial spin state

$$\Psi_{spin} = \frac{\alpha\alpha}{2} + \frac{\beta\beta}{2} + \frac{1}{\sqrt{2}}\left(\frac{\alpha\beta + \beta\alpha}{\sqrt{2}}\right) \tag{2.14}$$

calling

$$\begin{aligned} a_1 &= \frac{2}{\tau}\sin^{-1}\left[\frac{(E_1 + E_{2+})\tau}{2\hbar}\right], S_z = +1 \\ a_2 &= \frac{2}{\tau}\sin^{-1}\left[\frac{(E_1 + E_{2-})\tau}{2\hbar}\right], S_z = -1 \\ a_3 &= \frac{2}{\tau}\sin^{-1}\left[\frac{(E_1 + E_{20})\tau}{2\hbar}\right], S_z = 0 \end{aligned} \tag{2.15}$$

we have the total wave function

$$\begin{aligned} \Psi =& \frac{1}{\sqrt{2}}\left(\frac{2}{L}\sin\frac{n_1\pi x_1}{L}\sin\frac{n_2\pi x_2}{L} - \frac{2}{L}\sin\frac{n_1\pi x_2}{L}\sin\frac{n_2\pi x_1}{L}\right)\times \\ &\left(\frac{1}{2}\alpha\alpha e^{-ia_1 t} + \frac{1}{2}\beta\beta e^{-ia_2 t} + \frac{1}{2}(\alpha\beta + \beta\alpha)e^{-ia_3 t}\right) \end{aligned} \tag{2.16}$$

Evaluating $\langle S_{x_1} + S_{x_2}\rangle_t = \hbar$ we have from (Ref. 23)

$$\langle S_{x_1} + S_{x_2}\rangle_t = \frac{\hbar}{2}\cos(a_1 - a_3)t + \frac{\hbar}{2}\cos(a_3 - a_2)t \tag{2.17}$$

Thus two sinusoidal terms in the x spin polarization of a w gauge boson would signal both composite gauge boson structure and discrete time effects and the added preon constraint $e_1/m_1 = e_2/m_2$. If $e_1/m_1 \neq e_2/m_2$ we find that only the $S_z = \pm 1$ solution appear thus generating no x spin polarization precession. Thus the assumption of compositeness and the experimental existence of spin precession enforce the preon constraint $e_1/m_1 = e_2/m_2$.

If we now consider the added feature of the electric dipole moment of the w we have from Eq. (2.1)

$$\left(-\frac{\hbar^2}{2m_1}\frac{\partial^2}{\partial x_2^2} - \frac{\hbar^2}{2m_2}\frac{\partial^2}{\partial x_2^2} + M_0C^2\right)U(x_1, x_2) = E_1 U(x_1, x_2) \tag{2.18}$$

$$\begin{aligned} &\left[\frac{e}{m}(S_{z_1} + S_{z_2})B + P(S_{x_1} + S_{x_2})E + g\overrightarrow{S}_1.\overrightarrow{S}_2\right] \\ &\left[a_1\alpha\alpha + a_2\beta\beta + a_3\left(\frac{\alpha\beta + \beta\alpha}{\sqrt{2}}\right)\right] \\ &= E_2\left[a_1\alpha\alpha + a_2\beta\beta + a_3\left(\frac{\alpha\beta + \beta\alpha}{\sqrt{2}}\right)\right] \end{aligned} \tag{2.19}$$

$$\left[\frac{e_1}{m_1} = \frac{e_2}{m_2} = \frac{e}{m}\right]$$

In Eq. (2.19) we equate coefficients of $\alpha\alpha, \beta\beta, (\alpha\beta + \beta\alpha)/\sqrt{2}$ to find

$$\left(\frac{e}{m}\hbar B + g\frac{\hbar^2}{4} - E_2\right) a_1 + \left(\frac{PE\hbar}{\sqrt{2}}\right) a_3 = 0 \tag{2.20}$$

$$\left(-\frac{e}{m}\hbar B + \frac{g\hbar^2}{4} - E_2\right) a_2 + \frac{PE\hbar}{\sqrt{2}} a_3 = 0$$

$$a_1\left(\frac{PE\hbar}{\sqrt{2}}\right) + a_2\left(\frac{PE\hbar}{\sqrt{2}}\right) + a_3\left(\frac{g\hbar^2}{4} - E_2\right) = 0$$

The eigenvalues of the above system are

$$\begin{aligned} E_{2\pm} &= \frac{g\hbar^2}{4} \pm \sqrt{(PE\hbar)^2 + \left(\frac{e\hbar B}{m}\right)^2} \\ E_{20} &= \frac{g\hbar^2}{4} \end{aligned} \tag{2.21}$$

with normalized eigenstates in the basis $\begin{pmatrix} + \\ - \\ 0 \end{pmatrix}$ for S_z,

$$E_{2_+}, \quad \Psi_+ = \frac{1}{\sqrt{1 + \left(\frac{PE\hbar}{\sqrt{2}}\right)^2 \left(\frac{1}{(K-S)^2} + \frac{1}{(K+S)^2}\right)}} \begin{pmatrix} -\frac{PE\hbar}{\sqrt{2}(K-S)} \\ \frac{PE\hbar}{\sqrt{2}(K+S)} \\ 1 \end{pmatrix}$$

$$E_{2_-}, \quad \Psi_- = \frac{1}{\sqrt{1 + \left(\frac{PE\hbar}{\sqrt{2}}\right)^2 \left(\frac{1}{(K-S)^2} + \frac{1}{(K+S)^2}\right)}} \begin{pmatrix} -\frac{PE\hbar}{\sqrt{2}(K+S)} \\ \frac{PE\hbar}{\sqrt{2}(K-S)} \\ 1 \end{pmatrix}$$

$$E_{20}, \quad \Psi_0 = \frac{1}{\sqrt{1 + 2\left(\frac{PE\hbar}{\sqrt{2}K}\right)^2}} \begin{pmatrix} -\frac{PE\hbar}{\sqrt{2}K} \\ \frac{PE\hbar}{\sqrt{2}K} \\ 1 \end{pmatrix} \tag{2.22}$$

$$\begin{pmatrix} K = \frac{e\hbar B}{m}, \\ \\ S = \sqrt{(PE\hbar)^2 + K^2} \end{pmatrix}$$

When the linear combination of the three eigenstates in Eq. (2.22) is taken to insure

$$\langle S_{x_1} + S_{x_2} \rangle_{t=0} = \hbar$$

or

$$\Psi_{spin} = \frac{\alpha\alpha}{2} + \frac{\beta\beta}{2} + \frac{\alpha\beta + \beta\alpha}{2} \tag{2.23}$$

and the x spin polarization is found at time t to be

$$\langle S_{x_1} + S_{x_2} \rangle_t \tag{2.24}$$

we obtain a linear combination of three sinusoidal functions with three distinct frequencies that depend both on the spin quantum numbers and the spatial quantum numbers where we use the spatial energy and wave function from Eq. (2.7) and Eq. (2.8). Thus the signature to identify a w electric dipole moment would be a combination of tree distinct sinusoidal functions in the x spin polarization of the w^-. The magnitude of the frequencies would be a function of P and thus the diffferent frequencies would be a probe to P.

Conclusion.

It is interesting that a strong constraint on the two preon composite structure of the w^- follows simply from the fact that the w^- precesses in an external magnetic field. If $(e_1/m_1) \neq (e_2/m_2)$ then the state $(\alpha\beta + \beta\alpha)/\sqrt{2}$ is not permitted. This might also suggest that the preons electromagnetic properties are deeply related to the mechanism that generates their masses m_1, m_2. It might be that there is no need for "hypercolour" and the binding of the preons is purely electromagnetic in much the spirit of the binding mechanism that generates the 1.8 MeV(e^+ e^-) peaks in heavy ion collisions, namely a strongly coupled phase of Q.E.D.[26] The fact that an electric dipole moment for the w^- will generate three distinct sinusoidal functions in the (x) spin polarization while a pure magnetic dipole moment only generates two components Eq. (2.17) provides us with another probe to compositeness, the standart model predicts that w^- should have zero electric dipole moment and a non-zero electric dipole moment would most certainly arise from a composite w^- structure. The great experimental problem with w^- spin polarization is to obtain a significant number of precessions before the w^- decays. The only possible laboratory to obtain high fields is in the field of a pulsar where $B \simeq 10^{12}$ gauss. If w^-, w^+ are produced by some mechanism in a pulsar atmosphere, then a signature for w^- discrete time spin polarization precession would be temporal variations of the spin polarization induced in neighboring particles that we may observe in the cosmic rays. Thus w^- spin polarization would most likely have to be looked for in an astrophysical setting.

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