Spin Flip Spectra of A Particle With Composite Dyon Structure in Discrete Time Quantum Theory

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RESUME. En tenant compte d'un retournement simultané du spin d'un fermion composé et d'une transition interne d'un fermion de type préon se déplaçant dans le champ d'un dyon alors que le fermion de type préon et le dyon sont des composés de la structure composée d'un fermion composé, nous étudions le spectre des fréquences de retournement du spin dans un champ magnétique externe, en utilisant la théorie quantique à temps discret.

ABSTRACT. By allowing for a simultaneous spin flip of a composite fermion and an internal transition of a preonic fermion moving in the field of a dyon wherein the preonic fermion and dyon are composites of the composite structure of a composite fermion we study the spectra of spin flip frequencies in an external magnetic field using discrete time quantum theory.

Introduction

Elementary particle physics is now in a very interesting stage of development with the upcoming progress in accelerator physics making it possible to test modifications to the standard model in the TeV range. Super-symmetry [1], technicolour [2], grand-unification [3], compositness [4], as well as physics originating from the super-string [5] will all be under close scrutiny when higher energies at accelerators are obtained. Along with the great theoretical developments we have other profound questions that deserve both theoretical consideration and our curiosity in searching for experimental tests. Questions such as the completeness of quantum mechanics [6], or its possible underlying non-linear structure [7] tug at the very roots of the foundations of quantum theory. Wooters [8] has sought to answer the question of whether quantum theory emerges from the structure of information theory and Wheeler [9] has suggested a fundamental combinatorial approach in terms of a fundamental yes-no choice for quantum events.

One of the great achievements of lattice gauge theory has been to demonstrate that gauge invariance can be restored on a lattice but Lorentz invariance cannot [10]. If space and time in the end are discrete and form a countable number of points then the lack of Lorentz symmetry might suggest that symmetry in space time emerges after an averaging process and both gravitation and motion have an absoluteness associated with them. If this is the case very high energy experiments probing short time intervals and short spatial intervals may probe this discreteness. Actually, long ago Snyder [11] introduced a space-time lattice in Q.E.D. to eliminate the divergences and t'Hooft [12] has suggested the same procedure in quantum gravity to resolve the problems of renormalization and cut-offs. In a different sense T.D. Lee has introduced the idea of a countable discrete time in evaluating path integrals [13] and Caldirola has studied the discrete time difference version of the Schrodinger equation [14] as well as the radiation reaction equation [15] with finite time differences generating attractive features in the underlying theory. There are actually two fundamental approaches to a discrete time theory in quantum theory, the first admits a truly countable number of points and is effectively a lattice time theory, the second envisions a particle moving through the continuum of space time but due to an uncertainty principle operating on a microscopic level, the response of the particles wave function is a finite time interval removed from the point of application of the hamiltonian [16]. We have proposed two tests for the latter, the first being discrete time electron spin resonance [17], the second being discrete time difference spin polarization [18]. In a subsequent note we have discussed how discrete spatial effects may modify a neutron-interferometry experiment [19]. If discrete time differences really appear in quantum theory they would have the interesting consequence of generating a non-linear relation between the transition frequency for transitions and the energy difference between states [20]. In what follows we explore the consequence of this result for a composite fermion undergoing a spin flip coupled to an internal dyon transition that violates parity. Such a model may provide a test for discrete-time difference quantum theory as well as a possible probe to look for internal dyon structure to composite fermions.

Spin Flip Transition with Simultaneous Internal Dyon Transition

The motivation for studying spin flip transitions with a simultaneous internal dyon transition comes form an observation on the part of Pati [21] who recognized that since the magnetic coupling obeys

$$\frac{g^2}{\hbar c} \simeq \frac{1}{e^2/\hbar c} \simeq 137,$$

magnetic binding may provide an excellent binding mechanism to hold preons together within the composite fermions. The total magnetic charge of the composite fermion may vanish but the individual preons might suffer forces due to magnetic attraction. In fact we will envision the composite fermion to have composite mass (m), total electric charge ($-e$) and containing a heavy fermionic preon of mass m_p with electric charge ($-Ze$) moving about a dyon of electric charge ($Z_d e$) and magnetic charge (g). Although the mass of a heavy preon is $m_p \gg m$, it can be argued that due to either a chiral symmetry or a super-symmetry the total composite mass of the composite fermion is small in comparison to m_p ($m < m_p$). Recently Olsen and Osland [22][23] have discussed the bound states of a vector spin one particle in the field of monopole with stable bound states resulting. Tolkachev et. al. [24] have discussed the effect of Zeemen splitting of a dyogen atom (dyon + electric charge) in an external magnetic field and demonstrated that the character of the splitting is due to the breaking of parity of the dyon. Considering non-Abelian dyons, Gal'tsov and Ershov [25] have studied the bound state spectra of a scalar particle in the field of a $SU(2)$ dyon. Confining our attention to Abelian dyons both Frampton et. al. [26] and Zhang [27] have studied in detail the bound state spectrum of a charged fermion in the field of a scalar dyon and arrived at selection rules for a parity violating transition. Actually due to this parity violation the fermion dyon system has a non-vanishing electric dipole moment which can further serve as a probe to the presence of dyons in composite fermions. In a separate note Zhang-Jian zu [28] has discussed the electric and magnetic dipole moments of a dyon fermion system which might provide limits for their presence in composite fermions.

The purpose of this note is to study the spectra of spin flip frequencies in an external magnetic field of a composite fermion of charge ($-e$) when the external magnetic field does not appreciably perturb the internal structure of the dyon. This will be the case when the dyon is a component of the composite structure and is shielded from the external magnetic field by an outer-layer of magnetic charge which must exist since the total magnetic charge of the composite fermion must be zero.

We begin by writing the hamiltonian of a composite fermion of charge, $-e$, and mass m as

$$H = mc^2 + \frac{e}{mc}(S_z B) + H_d \tag{2.1}$$

Here H_d represents the hamiltonian of the heavy fermionic preon in the field of a dyon of electric charge $Z_d e$, magnetic charge g, with preon electric charge $-Ze$, mass (m_p). For the wave function we have

$$\psi = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \psi_d(r)\overline{T}(t) \tag{2.2}$$

Here $\begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$ = spin function of composite fermion, $\psi_d(r)$ = heavy preon wave function in field of dyon core $\overline{T}(t)$ = temporal part of wave function. For the discrete time difference generalization of the Schrodinger equation we have (Ref. 17) (T = discrete time interval)

$$E\psi = H\psi = \frac{i\hbar}{T}[\psi(t + \frac{T}{2}) - \psi(t - \frac{T}{2})] \tag{2.3}$$

We write

$$(mc^2 + \frac{e}{mc}S_z B)\begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = E_1 \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \tag{2.4}$$

$$H_d\psi_d(r) = E_2\psi_d(r) \tag{2.5}$$

$$E = E_1 + E_2 \tag{2.6}$$

$$E\overline{T}(t) = \frac{i\hbar}{T}[\overline{T}(t + \frac{T}{2}) - \overline{T}(t - \frac{T}{2})] \tag{2.7}$$

For the solution we have for spin up with dyon quantum numbers n_2, j

$$\psi_+ = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \psi_{D_{(n_2,j)}} e^{-\frac{2}{T}\sin^{-1}(\frac{E_+ T}{2\hbar})it} \tag{2.8}$$

$$E_+ = mc^2 + \frac{e\hbar B}{2mc} + E_{2,(n_2,j)} \tag{2.9}$$

For spin down with the dyon quantum numbers n_1, j

$$\psi_- = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \psi_{D_{n_1,j}} e^{-\frac{2}{T}\sin^{-1}(\frac{E_- T}{2\hbar})it} \tag{2.10}$$

$$E_- = mc^2 - \frac{e\hbar B}{2mc} + E_{2_{(n_1,j)}} \tag{2.11}$$

Here $E_{2(n,j)}$ represents the energy eigenvalue of the heavy preon in the field of dyon given in Ref. (27) as

$$E_{2(n,j)} = -\frac{m_p c^2}{2} \frac{(\frac{ZZ_d e^2}{\hbar c})^2}{[n + ((j+\frac{1}{2})^2 - q^2 - (\frac{ZZ_d e^2}{\hbar c})^2)^{1/2}]^2} \tag{2.12}$$

where we have subtracted off the rest energy since it is included in the composite mass m.

Here $-Ze$ = electric charge of fermionic preon, eZ_d = electric charge of dyon, n = principle quantum number,

$$j \geq |\, q \,| + \frac{1}{2} \quad , \quad |\, q \,| = |\, \frac{Zeg}{\hbar c} \,| \quad , \quad \frac{eg}{\hbar c} = \frac{N}{2}(N = 1, 2, \ldots) \tag{2.13}$$

j = total angular momentum of system of dyon and fermionic preon, m_p = heavy fermionic preon mass.

The condition $j \geq |\, q \,| + \frac{1}{2}$ and $Z_d < Z_d^c$ (where Z_d^c is critical dyon electric charge) are imposed to insure the lack of singularity ar $r = 0$ (j = half integer or integer). In Ref. (2è) Zhang pointed out that $\Delta j = 0$ for parity violating transitions of the fermionic preon-dyon system. For a spin flip accompanied by an internal dyon transition violating parity we have shown in a previous paper (Ref. 20) that the transition frequency has the form

$$W = \frac{2}{T}\sin^{-1}(\frac{E_+ T}{2\hbar}) - \frac{2}{T}\sin^{-1}(\frac{E_- T}{2\hbar}) \tag{2.14}$$

We consider a composite electron in the field of a pulsar ($B \approx 10^{12}$ gauss, m = composite mass of electrons). The following three cases are studied.

Case I :

$$E_d = E_{2(n,j)} \approx \frac{1}{10} \frac{(e\hbar B}{2mc}) \quad , \quad [mc^2 > \frac{e\hbar B}{2mc}] \quad , \quad T < 10^{-21} sec.$$

From Eq. (2.12)

$$\frac{m_p c^2}{2}(\frac{1}{137})^2 \approx \frac{1}{10}(\frac{e\hbar B}{2mc})$$

$m_p c^2 \simeq 50 MeV$ (Here we have written an order of magnitude estimate for the right hand side of Eq. (2.12)). For the spin flip frequency accompanied by a dyon transition violating parity ($\Delta j = 0$) we have

$$\begin{aligned} w \approx & \frac{eB}{mc} + \frac{E_{2(n_2,j)} - E_{2(n_1,j)}}{\hbar} \\ & + \frac{T^2}{24\hbar^3}[3(mc^2)^2(E_{2(n_2,j)} - E_{2(n_1,j)}) + 3(mc^2)^2(\frac{e\hbar B}{mc})] \end{aligned} \tag{2.15}$$

Where the higher powers of

$$E_{2(n,j)} \quad , \quad \frac{e\hbar B}{2mc}$$

are neglected since they are small compared to the terms above (we have approximated $\sin^{-1}(x) = x + x^3/3!$)

Case II :

$$E_d \approx E_{2(n,j)} \approx \frac{e\hbar B}{2mC} \quad , \quad (\frac{m_p c^2}{2})(\frac{1}{137})^2 \approx \frac{e\hbar B}{2mC}$$

$$[mc^2 > \frac{e\hbar B}{2mc} \quad , \quad 10^{-21} \quad \text{sec} \quad < T] \quad , \quad m_p c^2 \simeq 500 MeV$$

For the spin flip frequency accompanied by a dyon transition violating parity ($\Delta j = 0$) we have

$$\begin{aligned} w \simeq & \frac{eB}{mc} + \frac{E_{2(n_2,j)} - E_{2(n_1,j)}}{\hbar} \\ & + \frac{T^2}{24\hbar^3}[3(mc^2)^2(E_{2(n_2,j)} - E_{2(n_1,j)}) + 3(mc^2)^2\frac{e\hbar B}{mc}] \end{aligned} \tag{2.16}$$

Case III :

$$E_d \approx E_{2(n,j)} \approx (\frac{e\hbar B}{2mc})(100)[mc^2 \geq 100\frac{e\hbar B}{2mc}] \quad , \quad (10^{-21} sec > T),$$

$$\frac{m_p c}{2}(\frac{1}{137})^2 \approx 100(\frac{e\hbar B}{2mc})$$
$$m_p c^2 \approx 50GeV$$

For the spin flip frequency accompanied by an internal dyon transition violating parity we have

$$\begin{aligned} w \simeq \frac{eB}{mc} + \frac{E_{2(n_2,j)} - E_{2(n_1,j)}}{\hbar} \\ + \frac{T^2}{24\hbar^3}\begin{pmatrix} (mc^2+E_{2(n_2,j)})^3 - (mc^2+E_{2(n_1,j)})^3 \\ +\frac{3e\hbar B}{2mc}((mc^2+E_{2(n_2,j)})^2 + (mc^2+E_{2(n_1,j)})^2) \end{pmatrix} \end{aligned} \tag{2.17}$$

We have put the restriction $t < 10^{-21}$ sec. so as to prevent the quantity $ET/2\hbar$ from being greater than 1 in Eq. (2.14).

In case I we would find a series of lines which would have a frequency separation of about 10% of the basic spin flip frequency of eB/mc with small corrections dependent on (T^2) that are proportional to both the dyon transition energy and the magnetic field as exhibited in the term proportional to T^2. In Case II we could find a series of lines whose separation would fit Eq. (2.16) with small corrections due to discrete time terms dependent on T^2 and the energy difference of the dyon transition in Eq. (2.16) and the external magnetic field ($B \simeq 10^{12}$ gauss).

In Case III we would have a series of lines for $\Delta j = 0$, $\Delta n = 1, 2, 3, \ldots$ which would dominate over the basic spin flip frequency eB/mc and again countain small corrections due to the discrete time term that contain both the dyon initial and final energy as well as the external magnetic field.

A quantitative fit of the absorption spectrum due to spin flipping of particles accompanied by internal dyon transitions in the field of a pulsar would provide information on both the preon mass m_p and the dyon parameters Z_d, g along with the preon electric charge $-Ze$. Such a fitting of the spectrum might provide an excellent probe to compositeness of fermions as well as evidence for discrete time effects. The region of the E.M. spectrum that would provide this window can be estimated to be

$$w = \frac{eB}{mc} \approx \frac{(4 \cdot 8 \times 10^{-10})(10^{12})}{(10^{-27})(3 \times 10^{10})} \simeq 10^{19} sec^{-1}$$

We have used the electron as a model elementary composite fermion but any other changed fermion that is stable long enough could also be used.

In Ref. (26) Frampton et. al. have suggested looking for dyons in an astrophysical setting and our analysis has further suggested the pulsar atmosphere might provide the best probe to look for simultaneous spin flip dyon transitions obeying parity violating transitions.

Conclusion

Finding any of the signatures predicted in Case I, II and III would provide both evidence for internal parity violating dyon transitions of a composite fermion as well as possible discrete time difference effects. It is hoped that a close examination of the γ ray spectra energy from radiative γ ray bursts from condensed astrophysical objects might reveal spectra as that predicted above (29). In the high energy lab any anomalous parity violating radiative decays of a charged lepton (E_l^-) to another charged lepton (e_r^-)

$$\begin{array}{ccccc} E_L^- & \rightarrow & & \rightarrow & e_r^- \\ & & \downarrow & & \\ & & \gamma & & \end{array}$$

might be suggestive of an internal dyon transition accompanied by a spin flip transition where the excited lepton E_l^- actually has an internally excited dyon state, the mass difference between E_l^- and e_r^- being proportional to the heavy fermionic preon mass moving about the dyon core according to Eq. (2.12). In summary, a close examination of the astrophysical γ ray burst spectra as well as the search for anomalous parity violating decays of excited charged leptons would provide us with a probe to both discrete time difference Quantum Mechanics as well as internal dyon structure of composite charged fermions.

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