A Note on a Particle-Antiparticle Interaction

B.G. Sidharth
International Institute for Applicable Mathematics & Information Sciences
Hyderabad (India) & Udine (Italy)
B.M. Birla Science Centre, Adarsh Nagar, Hyderabad - 500 063 (India)

Abstract

We develop an iso spin like formulation with particles and their anti particle counterparts. This leads to a new shortlived interaction between them, valid at very high energies and mediated by massive particles. We point out that evidence for this is already suggested by the very recent observations by the CDF team at Fermi Lab.

It is well known that the Dirac equation [1, 2] is

$$(\gamma^\mu p_\mu - m)\psi = 0 \tag{1}$$

Here γ^μ are 4×4 matrices obeying the Clifford algebra and ψ is a 4 component wave function (spinor). ψ can be written as,

$$\psi = \begin{pmatrix} \phi \\ \chi \end{pmatrix} \tag{2}$$

where ϕ and χ are 2-component spinors, ϕ being the "large" or positive energy component of ψ and χ is the "small" or negative energy component which is such that

$$\chi \sim (\frac{v}{c})^2\phi \tag{3}$$

It is also known that this picture gets reversed at high energies where $v \to c$ (Cf.refs.[1, 2]).
We observe that (1) can be written as:

$$\imath\hbar(\partial\phi/\partial t) = c\tau \cdot (p - e/cA)\chi + (mc^2 + e\phi)\phi,$$

$$\imath\hbar(\partial\chi/\partial t) = c\tau \cdot (p - e/cA)\phi + (-mc^2 + e\phi)\chi. \tag{4}$$

We can see from (4) that (in the absence of electromagnetic subsection),

$$t \to -t, \quad \phi \to -\chi \tag{5}$$

Let us now consider intervals near the Compton scale, where as we know $v \to c$, and χ no longer is the "small" component.

At the Compton scale we have the phenomenon of Zitterbewegung or rapid unphysical oscillation. It has been pointed out that in this case, [3] that time can be modelled by a double Weiner process and can be described as follows

$$\frac{d_+}{dt}x(t) = \mathbf{b}_+ \, , \, \frac{d_-}{dt}x(t) = \mathbf{b}_- \tag{6}$$

where for simplicity we consider in the one dimensional case. This equation (6) expresses the fact that the right derivative with respect to time is not necessarily equal to the left derivative. It is well known that (6) leads to the Fokker Planck equations [4, 5]

$$\partial\rho/\partial t + div(\rho\mathbf{b}_+) = V\Delta\rho,$$

$$\partial\rho/\partial t + div(\rho\mathbf{b}_-) = -U\Delta\rho \tag{7}$$

defining

$$V = \frac{\mathbf{b}_+ + \mathbf{b}_-}{2} \quad ; U = \frac{\mathbf{b}_+ - \mathbf{b}_-}{2} \tag{8}$$

We get on addition and subtraction of the equations in (7) the equations

$$\partial\rho/\partial t + div(\rho V) = 0 \tag{9}$$

$$U = \nu\nabla ln\rho \tag{10}$$

It must be mentioned that V and U are the statistical averages of the respective velocities and their differences. We can then introduce the definitions

$$V = 2\nu\nabla S \tag{11}$$

$$V - \imath U = -2\imath\nu\nabla(ln\psi) \tag{12}$$

We refer the reader to Smolin [6] for further details. We now observe that the complex velocity in (12) can be described in terms of a positive or uni directional time t only, but with a complex coordinate

$$x \to x + \imath x' \tag{13}$$

To see this let us rewrite (8) as

$$\frac{dX_r}{dt} = V, \quad \frac{dX_\imath}{dt} = U, \tag{14}$$

where we have introduced a complex coordinate X with real and imaginary parts X_r and $X_\imath$, while at the same time using derivatives with respect to time as in conventional theory.
From (8) and (14) it follows that

$$W = \frac{d}{dt}(X_r - \imath X_\imath) \tag{15}$$

This shows that we can use derivatives with respect to the usual time derivative with the complex space coordinates (13) (Cf.ref.[7].
Generalizing (13), to three dimensions, we end up with not three but four dimensions,

$$(1, \imath) \to (I, \tau),$$

where I is the unit 2×2 matrix and τs are the Pauli matrices. We get the special relativistic Lorentz invariant metric at the same time.
That is,

$$x + \imath y \to I x_1 + \imath x_2 + j x_3 + k x_4, \tag{16}$$

where $(\imath, j, k)$ momentarily represent the Pauli matrices; and, further,

$$x_1^2 + x_2^2 + x_3^2 - x_4^2 \tag{17}$$

is invariant, thus establishing a one to one correspondence between (16) and Minkowski 4 vectors as shown by (17).
In this description we would have from (16), returning to the usual notation,

$$[x^\imath \tau^\imath, x^j \tau^j] \propto \epsilon_{\imath jk} \tau^k \neq 0 \tag{18}$$

(No summation over $\imath$ or j) Alternatively, absorbing the $x^\imath$ and $\tau^\imath$ into each other, (18) can be written as

$$[x^\imath, x^j] = \beta \epsilon_{\imath jk} \tau^k \tag{19}$$

Equation (18) and (19) show that the coordinates no longer follow a commutative geometry. It is quite remarkable that the noncommutative geometry

(18) has been studied by the author in some detail (Cf.[4]), though from the point of view of Snyder's minimum fundamental length, which he introduced to overcome divergence difficulties in Quantum Field Theory. Indeed we are essentially in the same situation, because for our positive energy description of the universe, there is the minimum Compton wavelength cut off for a meaningful description as is well known [8, 9, 10]. Following Feshbach and Villars (loc.cit) we consider (2) to describe particles and anti-particles : specifically a particle anti-particle pair depending on the upper or lower component predominating.

Proceeding further we could invoke the $SU(2)$ and consider the gauge transformation [11]

$$\psi(x) \to exp[\frac{1}{2}\imath g\tau \cdot \omega(x)]\psi(x). \tag{20}$$

This is known to lead to a gauge covariant derivative

$$D_\lambda \equiv \partial_\lambda - \frac{1}{2}\imath g\tau \cdot \bar{W}_\lambda, \tag{21}$$

We are thus lead to vector Bosons $\bar{W}_\lambda$ and an interaction like the weak interaction, described by

$$\bar{W}_\lambda \to \bar{W}_\lambda + \partial_\lambda \omega - g\omega\Lambda\bar{W}_\lambda. \tag{22}$$

However, we are this time dealing, not with iso spin, but between positive and negative energy states as in (4) that is particles and antiparticles. Also we must bear in mind that this new non-electroweak force between particles and anti particles would be short lived as we are at the Compton scale [12]. These considerations are also valid for the Klein-Gordon equation because of the two component formulation developed by Feshbach and Villars [13, 14]. There too, we get equations like (4) except that ϕ and χ are in this case scalar function. We would like to re-emphasize that our usual description in terms of positive energy solutions is valid above the Compton scale (Cf.refs.[1, 2]). To put it another way, equation (2) describes a new spinor in a "superspin" space.

Thus we are lead to a new short lived interaction (as we are near the Compton scale), mediated by vector Bosons $\bar{W}$.

With regard to the $\bar{W}$ acquiring mass, apart from the usual approach, we can note the following. Equation (18) underlines the non-commutativity of spacetime, and under these circumstances it has been argued that there is a

break in symmetry that leads to a mass being acquired exactly as with the Higgs mechanism [15, 4].
Let us see this in greater detail. The Gauge Bosons would be massless and hence the need for a symmetry breaking, mass generating mechanism.
The well known remedy for the above situation has been to consider, in analogy with superconductivity theory, an extra phase of a self coherent system (Cf.ref.[16] for a simple and elegant treatment and also refs. [17] and [11]). Thus instead of the gauge field A_μ, we consider a new phase adjusted gauge field after the symmetry is broken

$$\bar{W}_\mu = A_\mu - \frac{1}{q}\partial_\mu \phi \tag{23}$$

The field $\bar{W}_\mu$ now generates the mass in a self consistent manner via a Higgs mechanism. Infact the kinetic energy term

$$\frac{1}{2}|D_\mu \phi|^2 \quad , \tag{24}$$

where D_μ in (24) denotes the gauge derivative, now becomes

$$|D_\mu \phi_0|^2 = q^2 |\bar{W}_\mu|^2 |\phi_0|^2 \, , \tag{25}$$

Equation (25) gives the mass in terms of the ground state ϕ_0.
The whole point is as follows: The symmetry breaking of the gauge field manifests itself only at short length scales signifying the fact that the field is mediated by particles with large mass. Further the internal symmetry space of the gauge field is broken by an external constraint: the wave function has an intrinsic relative phase factor which is a different function of spacetime coordinates compared to the phase change necessitated by the minimum coupling requirement for a free particle with the gauge potential. This cannot be achieved for an ordinary point like particle, but a new type of a physical system, like the self coherent system of superconductivity theory now interacts with the gauge field. The second or extra term in (23) is effectively an external field, though (25) manifests itself only in a relatively small spatial interval. The ϕ of the Higgs field in (23), in analogy with the phase function of Cooper pairs of superconductivity theory comes with a Landau-Ginzburg potential $V(\phi)$.
Let us now consider in the gauge field transformation, an additional phase term, $f(x)$, this being a scalar. In the usual theory such a term can always be

gauged away in the U(1) electromagnetic group. However we now consider the new situation of a noncommutative geometry referred to above,

$$[dx^\mu, dx^\nu] = \Theta^{\mu\nu}\beta, \beta \sim 0(l^2) \tag{26}$$

where l denotes the minimum spacetime cut off. Equation (26) is infact Lorentz covariant. Then the f phase factor gives a contribution to the second order in coordinate differentials,

$$\frac{1}{2}\left[\partial_\mu B_\nu - \partial_\nu B_\mu\right]\left[dx^\mu, dx^\nu\right]$$
$$+\frac{1}{2}\left[\partial_\mu B_\nu + \partial_\nu B_\mu\right]\left[dx^\mu dx^\nu + dx^\nu dx^\mu\right] \tag{27}$$

where $B_\mu \equiv \partial_\mu f$.
As can be seen from (27) and (26), the new contribution is in the term which contains the commutator of the coordinate differentials, and not in the symmetric second term. Effectively, remembering that B_μ arises from the scalar phase factor, and not from the non-Abelian gauge field, A_μ is replaced by

$$A_\mu \to A_\mu + B_\mu = A_\mu + \partial_\mu f \tag{28}$$

Comparing (28) with (23) we can immediately see that the effect of noncommutativity is precisely that of providing a new symmetry breaking term to the gauge field, instead of the ϕ term, (Cf.refs. [18, 19]) a term not belonging to the gauge field itself.
On the other hand if we neglect in (26) terms $\sim l^2$, then there is no extra contribution coming from (27) or (28), so that we are in the usual non-Abelian gauge field theory, requiring a broken symmetry to obtain an equation like (28). This is not surprising because if we neglect the term $\sim l^2$ in (26) then we are back with the usual commutative theory and the usual Quantum Mechanics.
It is quite remarkable that after the new interaction with the $\bar{W}$ particles was proposed, the CDF team in Fermi Lab announced a new force and particle in proton anti-proton interactions that matches the above [20]. The CDF rules out the Higgs Boson because the decays are much too rapid for this to be a Higgs Boson. The experimental result has been checked to a 3σ plus level of confidence, that is there is only a one in thousand chance for it to be wrong.Subsequently this was pushed up to nearly five sigma the desired level though the Dzero could not show up this finding If however the above theory

and experiment are talking about the same thing then surely the confidence level increases. Further experimental results are awaited. Other possible explanations included techni-colour.

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