SUGRA INTERACTIONS WITHIN FLAVOR TRIPLETS

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Abstract. A specific new quark permits that flavor generations constitute a representation of the 3-dimensional SU(3) symmetry that characterizes the \(Z_3\) orbifold. In this context, color and local supersymmetry bind triplets and 4-tuplets into composite fields of spin 3/2 and spin 2; and the symmetry \(E_8\) that characterizes (the observable sector of) 10-spacetime is interpreted as having reduced to \(SU(5) \times SU(3)_{3-D}\): e.g. to a locally supersymmetric unification of flavor generations and of quark colors and basic \(I_3\) classes that are devoid of color and hypercharge. In this context superunified interactions occur to color bound quarks that are experiencing asymptotic freedom within baryons. Quark-lepton transitions are produced, but quickly reverse, preserving flavor triplets. The symmetry consisting of six quark classes and six lepton classes is also maintained because the predicted quark is an anomalous (left-handed) version of the strange quark.

1. Introduction

The current status of high energy physics is plagued by a difficult problem: that SUSY SU(5) predicts proton decay that has not, after several years of intensive experimental activity, been observed. This problem may occur because local supersymmetry is relevant at energy levels lower than traditionally assumed. Specifically, there are indications that supergravity is significant at the GUT level–around \(10^{16}\) GeV. Thus it may be that SUSY GUTs should be replaced by, or modified as aspects of supergravity. However, the only known finite supergravity theory is that which emerges from the theory of heterotic superstrings. Unobserved superpartners can probably be relegated to the hidden sector of 10-spacetime, but this is a discussion for another occasion. Assuming that this can be done, the question arises regarding a physical representation of the 3-dimensional SU(3) symmetry that characterizes the \(Z_3\) orbifold. This representation can be formulated if one admits a specific new quark: an anomalous, left-handed version of the strange quark–anomalous because this quark associates with a strangeness number of zero (left-handedness implies that \(I_3 \neq 0\), which, in the context of the postulated symmetry requires that \(Y=1/3\). Thus, \(Y=B+S\) implies that \(1/3=1/3+S\), or that \(S=0\)). The postulated quark is characterized as a strange quark because associated quantum numbers, other than strangeness, are those of the strange. In the proposed model moreover, the new quark is the generational partner of the charmed quark. The newly introduced quark permits that quark generations be organized into three triplet–anti-triplet configurations, all of which contain the right-handed strange and left-handed anti-strange quarks [J. Towe, 1997].

If the above described triplets are symmetrically combined, so that none is distinguished from any other, and so that degeneracy is avoided (so that the strange and anti-strange quarks occur only once), then one obtains a physical representation of
a 3-dimensional SU(3) symmetry, which is spanned by the basis:

\[ e^{in2\pi/3}I_3, \ Y : n = 1, 2, 3. \]

This configuration is depicted by the first figure. (The proposed model should be compared with the traditional theory of quark generations [D. Nordstrom, 1992].)

If the symmetry that is spanned by expression 1.1 is imbedded into the point group of the relevant torus, then this 3-dimensional SU(3) symmetry becomes a physical representation of the \( Z_3 \) orbifold. However, the proposed model immediately elicits an important question: Does the postulated physical representation of \( SU(3)_{3-D} \) also satisfy local supersymmetry, containing the spin-(3/2) and spin-2 fields that are necessary for supergravity interactions? The answer is that it can. The triplet–anti-triplet configurations that are combined to yield the configuration depicted by the first figure are usually regarded as of spin 1/2, but they can be of spin 3/2 if the strange and anti-strange quarks are anti-aligned with the other quarks and anti-quarks. This characteristic will be imposed upon the representation that is depicted by the first figure; i.e. upon the generic representation of 3-dimensional SU(3) that was proposed.

In this context, one consults the Figure 4 configuration, observing that there are three orientations of the \( I_3 \)-axis about the hypercharge axis for which a triplet and anti-triplet lie on the \((I_3-Y)\)-plane. One of these orientations corresponds to the up down and strange quarks. A second corresponds to the charmed, 7 and strange quarks (7 referring to the predicted quark) and the third corresponds to the top bottom and strange quarks.

For each of the above described orientations of the \( I_3 \) axis, there are 4 quarks and 4 anti-quarks that lie off the \((I_3-Y)\)-plane; and two options for organizing these into spin-2 4-tuplets and anti-4-tuplets; e.g. for the UDS triplet, there are the 4-tuplet \( G=C\bar{7}TB \) and anti-4-tuplet \( \bar{G}=\bar{C}7\bar{T}B \); and the 4-tuplet \( g=C\bar{7}TB \) and anti-4-tuplet \( \bar{g}=\bar{C}7\bar{T}B \). Note that \( G \) and \( \bar{G} \) are respectively characterized by a charge of 2/3 and one color, and by a charge of -2/3 and one anti-color; and that \( g \) and \( \bar{g} \) are of charge zero and colorless. Thus, there is a total of 6 spin-2 4-tuplets. Because the adjoint representation of the GL(4) group contains 6 elements, it is postulated that the 6 proposed spin-2 4-tuplets constitute an irreducible, adjoint representation of GL(4), just as the spin-(1/2) and spin-(3/2) baryons constitute irreducible representations of SU(3). The 6 proposed 4-tuplets are therefore regarded as composite, spin-2 fields. G-fields will subsequently be referred to a type I fields and \( g \)-fields as type II fields. One can now answer the question that was posed above: The proposed version of the Figure 4 flavor representation of 3-dimensional SU(3), in which triplets are of spin-(3/2) does satisfy local supersymmetry, containing the spin-2 and spin-(3/2) fields that are necessary for supergravity interactions.

In the above postulated context the symmetry \( E_8 \), corresponding to the observable sector of 10-spacetime, is interpreted as having reduced to SU(5)xSU(3)_{3-D}; i.e. is interpreted as a unification of the fermionic flavor generations with quark colors and the basic \( I_3 \) classes that are devoid of hypercharge and color.

The nature of basic (first order) supergravity interactions is determined by the locally supersymmetric Lagrangian, which prescribes that SUSY vertices be generated by action of a graviton vertex operator upon a gravitino (spin-(3/2) field), which produces a graviton (spin-2 field). The specific interactions that will be considered here are 2nd order corrections of the basic, locally supersymmetric interactions that are required by the locally supersymmetric Lagrangian; and are
based upon the asymptotic freedom that is experienced by color-bound quarks at close range. Specifically, it is proposed that interactions between the proposed spin-2 fields and spin-(3/2) triplets are actually interactions between spin-2 fields and 'valance quarks' (quarks that experience asymptotic freedom within triplets, and in this context, absorb or radiate spin-2 fields or anti-fields). If the spin-2 and spin-(3/2) fields that we have proposed enter into this kind of interaction, then quark-lepton transitions can occur, while baryon decay is avoided. The proposed interactions will now be considered in some detail.

2. Supergravity Interactions

The action of pure supergravity is given by a sum of two integrals:

\[ \frac{-1}{2\kappa} \int d^4x |det e| R - \frac{1}{2} \]

(e = e^m_\mu is the verbein, where \( \mu \) is a world sheet index and \( m \) is a local Lorentz index) and

\[ \int d^4x \epsilon^{\mu
u\rho\sigma} \psi^{R}_{\mu} \gamma^5 \nabla_{\rho} \psi^{L}_{\sigma} \]

i.e. by the sum of the standard Einstein action where \( R \) represents the curvature scalar, and the action of the Rarita-Schwinger field, which is covariantized in terms of a covariant derivative to which an extra term has been added. This covariant derivative differs from the ordinary covariant derivative by a term quadratic in the Rarita-Schwinger field, which is necessary to achieve invariance of the action at order \( \kappa^2 \). The action is invariant, to this order of \( \kappa \), under local supersymmetry transformations \( e^\epsilon(x)Q \), where \( \epsilon \) is a Majorana spinor parameter that is a function of spacetime position, and \( Q \) is a Majorana generator of supersymmetry.

The interaction vertex that arises from this action involves a gravitino state of momentum \( k \) that corresponds to a vector-spinor \( u^\mu \). In the context of heterotic string theory, graviton emission from this gravitino ground state is produced by interaction of the gravitino with a bosonic right-moving (Neveu-Schwarz) prescription, which is tensored with a fermionic left-moving (Ramond) prescription. This 'graviton vertex operator' is given by a sum of the following terms:

\[ \epsilon_{\mu\nu} [\partial_{\tau} X^{R}_{\mu}(0)] \]

and

\[ \frac{1}{2} [\psi^{R}_{\mu}k \psi^{R}(0)] \psi^{R}_{\tau}(0)e^{-ikX} \]

[J. Bailen, 1994].

As explained above, the interactions to be considered here are 2nd order corrections of the basic locally supersymmetric interactions (those consisting of the vertices that are described above) which corrections are due to the asymptotic freedom experienced at short range by quarks within flavor triplets. In practice, each interaction of interest involves an asymptotically free quark that simultaneously absorbs a \( \overline{G} \)-field (a type I anti-field of spin-2) and radiates a \( \overline{F} \)-field (a type II anti-field of spin-2). Such interactions always produce leptons [J. Towe, 2003]. There are three options for the occurrence of this fundamental interaction. One is that represented when \( \overline{G}_R \) is absorbed and \( \overline{F}_R \) is radiated by a down quark, \( D_L \), producing an LH electron. A second option is provided by the case in which \( \overline{G}_R \) is absorbed,
and $\overline{f}_R$ is simultaneously radiated by a $U_L$, to produce a colorless, LH, spin-(1/2) particle with a charge of zero; i.e. an LH electron's neutrino. A third realization of the postulated interaction is provided by the case in which a $G_R$ is absorbed, and a $\overline{f}_R$ is simultaneously radiated by a strange quark within an $\Omega$ (triplets SSS), producing a right-handed electron. The $\overline{G}$ and $\overline{f}$ fields are anti-aligned with the valance quark in the interaction just described, so that they behave essentially as LH fields.

The above described interactions are idealized in that supersymmetric interactions occur at vertices of triplet separation or recombination. In these special cases, the interactions can be mediated exclusively by spin-2 fields; but if a supersymmetric interaction occurs between a vertex of triplet separation and recombination, then a spin-1 field (an element of the adjoint representation of SU(5)) must be absorbed together with a type I spin-2 anti-field and a spin-1 field must be radiated together with a type II, spin-2 anti-field. Finally, if a baryon is of spin(-(1/2)), then a spin-1 field must be absorbed and radiated by the valance quark even if the supersymmetric interaction occurs at a vertex of triplet separation or recombination.

Specifically, inspecting the second figure, one observes that the admission of an X-particle permits that vertices preserve supersymmetry. In general then, GUT interactions are necessary to permit the general implementation of the proposed superunification, but they are only admitted as aspects of locally supersymmetric interactions.

3. Conclusion

It was shown that if a specific new quark is introduced, and if the superpartners of the fermions are relegated to the hidden sector of the $(E_8 \times E_8)$ 10-spacetime domain, then the quark generations (in the observable sector) can be organized into three triplet–anti-triplet configurations that contain the strange and anti-strange quarks as common elements. Secondly it was argued that if these triplet–anti-triplet configurations are symmetrically combined, so that none is distinguished from any other (and the degeneracy disappears: strange and anti-strange quarks occurring only once), then they form a realization of the relevant 3-dimensional SU(3) symmetry. Thirdly it was observed that the proposed flavor configuration also satisfies local supersymmetry, containing the necessary spin-(3/2) and spin-2 fields.

In the above described context, the symmetry $E_8$ of (the observable sector of) 10-spacetime, was interpreted as having reduced to SU(5)$\times$SU(3)$_{3-D}$; i.e. was interpreted as a unification of the fermionic flavor generations with quark colors and basic $I_3$ classes that are devoid of color and hypercharge.

It was argued that interactions of spin-2 fields with baryons are actually 2nd order corrections of basic supergravity interactions– corrections in which spin-2 fields are absorbed and radiated by valance quarks (quarks that experience asymptotic freedom within triplets and, in this context, undergo gravitational interactions). Specifically, it was argued that asymptotic freedom permits the coupling of a $U$, $D$ or $S$ singlet to a spin-2 field. It was emphasized that these couplings result in quark-lepton transitions that quickly reverse, preserving quark triplets. It was observed that the interactions depicted by figures 5-7 are idealized (probably naive) in that supersymmetric interactions occur at vertices of triplet separation or recombination. It was emphasized that if a locally SUSY interaction occurs between
a vertex of triplet separation and a vertex of recombination, then that interaction must involve the absorption of a spin-1 field together with a type I spin-2 anti-field, and the radiation of a spin-1 field together with the radiation of a type II, spin-2 anti-field. Finally, it was stated that if a supersymmetric interaction occurs within a baryon of spin-(1/2), then a spin-1 field must be involved even if the interaction does occur at a triplet separation vertex (or recombination vertex). It was therefore concluded that GUT interactions are necessary for the general implementation of the proposed superunification, but such interactions were only admitted as aspects of local supersymmetric interactions. The postulated interactions are remarkable because they produce quark-lepton transitions while avoiding baryon decay. Six-quark–six-lepton symmetry is also preserved because the required quark is an anomalous (left-handed) version of the strange quark.

References

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