International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Lorentz Breaking Supersymmetry

Suhail Ahmad

Department of Physics, Cluster University of Srinagar, India
ahsuhail985[at]gmail.com

Abstract: ***Lorentz symmetry is considered essential ingredient in various quantum field theories. It is seen we can introduce various lorentz violating quantum field theories as susy gauge theories which are shown to be lorentz violating while conforming to certain algebra observed by them. The methodology of superfields is a powerful tool to study, among other approaches, the per-turbative aspects of super symmetric theories. Even though SUSY and its algebra is closely related to Lorentz symmetry, we could extend the super-field formalism to include the Lorentz violating terms, therefore allowing us to use the most attractive properties of superspace formalism. In this paper an attempt will be made to review the study of these susy-gauge theories and their lorentz violating properties. It is seen by attempting this exercise we can explain many facts of lorentz violating theories***

Keywords: super symmetry, lorentz symmetry, super space formalism

1. Introduction

It has been known for some time now that the idea of Lorentz in-variance is not sacrosanct and hence it can be violated in certain constructions of super- symmetric quantum field theories[6],where the violation can get manifested at a given energy scale depending on the model which has been incorporated. From the survey of literature it can been seen that the violation of Lorentz symmetry can help us explain different issues ranging from infrared modifications to gravity and related issues in cosmology as well addressing issues like nature of dark matter, dark energy, Lorentz violating massive gravity, ghost condensate, Gale- lions etc.

Besides there have also been certain constructions where we get renormalizable theories of quantum gravity which are Lorentz violating at high energies. Even though it is known that Lorentz symmetry is a symmetry which has been tested experimentally to the best of knowledge till date, it will be a challenge to construct theories with mechanisms which are although Lorenz violating but should give us in their low energy limits the results reproduced from well known facts of standard model of particle physics. It has been known that truncated super-symmetrical algebra without boosts still preserves the algebra and the non-relativistic version of this super-symmetric algebra is Lorentz violating from its basic construction.

There have been studies particularly Kosteclesky- Burgers reconstruction[4] where the deformed susy algebra can be applied in a certain way to get Lorentz violating terms[5] on component level with dimensions which may not be the same or they can be higher than four. Another way of getting the Lorentz violating mechanisms is to involve extra super-fields whose components depend on Lorentz breaking parameters [7] albeit with certain CPT odd Lorentz breaking terms in component level or addition of Lorentz breaking super field terms. It is to be noted that in variance under non relativistic susy in general is Lorentz violating and hence it is explicitly possible to construct the Lorentz violating terms in the Lagrangian. However, as we have noted, the new theory involving the Lorentz symmetry breaking can be reduced, through simple rules, to the usual Lorentz invariant theory, only if it is being considered in the purely scalar sector.

If one deals with vector or spin or fields whose action involve metric contracted to fields, the redefinition of coordinates will not give us the freedom to redefine completely all the action, since it will imply in variations of the fields which are not suggested by the initial structure of our modification of the super- symmetry generators. The field content of these theories is generally in dimensions greater than four or higher. Thus it is the re-normalized version of these Susy field theories which preserve Lorentz invariance or its accidental emergence in a certain range. In this paper we are going to use Kosteclesky-Burgers construction while introducing deformation in the algebra we will reproduce some Lorentz violating terms or Aether like terms while effective action can be derived from super-field approach as in the simplest Lorentz invariant case

2. Lorentz Violating Terms from KB Construction

The main exposition of this work is to deform super symmetry in a manner such that although Lorentz in-variance is broken it will leave super symmetry in- tact. The procedure would take into account application of algorithm of super field calculations of the effective potential with results [8, 9] known in the literature. The emphasis being first towards construction of deformed SUSY and subsequently calculating effective potential of simplest super-fields .If we start with the deformation of SUSY generators in 3+1 dimensions

$$D_\alpha = \partial_\alpha + i\theta^\beta \sigma^m_{\beta\alpha} \nabla_m \qquad (1)$$

$$D_{\alpha\cdot} = \partial_\alpha + i\theta^\beta \sigma^m_{\beta\alpha} \nabla_m \qquad (2)$$

The modified susy generators relates lorentz group to SL (2R) which are co- variant in three dimensional space time with spinor representations acting on Majorana two component spinor and hence spinor susy generators are Hermitian. To extend normal space to deformed super space let us define the deformed super symmetry generators as those which is the derivative with respect to the Grassmannian super space coordinates and which is also a covariantized space- time derivative.

Without generalising we can chose to assume an aether-like form $kmn = \alpha u_m u_n$ where u_m is a constant vector, and is some number. Therefore we can refer to this algebra as to the aether-like generalization of the super symmetry algebra, and denominate the theories constructed on its base as the ether-like super field super-symmetric Lorentz-breaking theories. We will first consider a constant vector field. Now as vμ is a constant vector field, so we can write $[v]^2 = v^\mu v^\mu$ where it is = 1 for space like = -1 for time like = 0 for light like cases .Now this vector field can be noted in the space like cases we have $E^2 = P^i P_i + m^2 + 2\alpha + \alpha^2$) $u \rightarrow p \rightarrow 2$. So, the dynamics can be consistently define for, $\alpha > 0$, $\alpha < 0 > 0$, < 0, if $|\alpha| << 0 << 0$. However for alpha < 0 the theory turns out to be degenerate and unstable. In the time like case, we have $E^2 (1-\alpha^2) = p^i p_i + m^2$ and so the dynamics is consistent for all values α expect α= 1. Finally, for the light like case, we have $E(1-2\alpha) = 2\alpha\sqrt{p^i p_i}\sqrt{p^i p_i}(1+2\alpha+4\alpha^2) + m^2$. So, the dynamics is consistent for $\alpha << 1$. Now we will deform the super-symmetry using this vector field, in such a way that Lorentz symmetry is broken without breaking any super symmetry

3. Covariant Derivatives

As we know in ordinary flat space-time the usual coordinate derivative ∂_α is translation invariant. The translation generator P_a which is represented by $\partial\alpha\alpha^{\cdot}$ commutes with itself. In super-symmetric theories the super-translation generator Q_α has nontrivial anti commutator, which is not invariant under super- translations. It can also be shown that coordinate derivatives $\partial_\alpha \partial_\alpha \alpha^{\cdot}$ are also not invariant.

There is a simple way to construct derivatives that are invariant under super symmetric transformations generated by Q_α, Q_α. and are covariant under Lorentz, chiral, and isospin rotations generated by $J_\alpha\beta$A and T_{ab} .The construction of Lorentz violating super symmetric algebra has to be proceeded with certain steps before we modify the construction by certain set of operations where $J\partial\alpha \rightarrow \partial\alpha$ .To compute the explicit forms of $D's$ and $Q's$ we define

$$D_\alpha = -i\theta_\alpha + \theta^\alpha P_\alpha \alpha^{\cdot} \quad (3)$$

$$D^{\cdot}_\alpha = -i\theta_\alpha + \theta^\alpha P_\alpha \alpha^{\cdot} \quad (4)$$

The method of induced representations helps us to find the actions of super Poincare generators in superspce which can also be used to find covariant derivatives. For $N = 1$ when acting on superfields they have the form

$$D_\alpha = \partial_\alpha + \frac{1}{2}\theta_\alpha i(\gamma^\mu \partial_\mu)_\alpha \alpha^{\cdot} + (\gamma^\mu \partial^\nu K_\mu \nu)_\alpha \alpha^{\cdot} \quad (5)$$

$$D_\alpha = \partial_\alpha + \frac{1}{2}\theta_\alpha i(\gamma^\mu \partial_\mu)_\alpha \alpha^{\cdot} + (\gamma^\mu \partial^\nu K_\mu \nu)_\alpha \alpha^{\cdot} \quad (6)$$

We can thus define these operators that are invariant under super-translations and also under ordinary translations. Basing on the Berger-Kostelecky construction we can develop the super-field approach for constructing the Lorentz- breaking super-symmetric field theories.

This approach turns out to be no more complicated as the standard super- graph technique whose examples of application are present in the papers given in literature and the results do not crucially differ from the usual case. We note that if the deformation of the super-symmetry algebra is small, the dynamics continues to be consistent. It is interesting to note that, first, this scheme is essentially CPT-even, second, in principle, one can choose the Lorentz-breaking matrix to be anti-symmetric, and in this case the integral measure is not corrected for the infinitesimal effects. In other words, we can succeed to reconcile Lorentz symmetry breaking and the super-symmetry in a rather simple way. In principle, the calculations for the super-gauge theories can be carried in the same way.

4. Discussion

The methodology of super fields is a powerful tool to study, among others, perturbative aspects of super-symmetric theories. Even though SUSY and its algebra is closely related to Lorentz symmetry, we could extend the super-field formalism to include the Lorentz violating terms, therefore allowing us to use the most attractive properties of super-space formalism. From a related construction the aether super-space is a natural way to deal with Lorentz violating super- symmetric models. In this context, some applications of the aether super-space techniques in three and four-dimensional space-time, we can discuss perturbative aspects of super symmetric quantum electrodynamics and Super-Chern-Simons matter model.

It would be interesting to see these effects to explore and from the methodological viewpoint, to see whether the calculations essentially differ from the usual Lorentz-invariant case. We are able to reconstruct Lorentz violating mechanisms in super-symmetric field theories from which certain Lorentz violating terms can be accounted in the Lagrangian of the field theory. We can arrive at Lorentz violating terms from KB formalism. The main exposition of work is to deform super symmetry in a manner that although Lorentz invariance is broken it will leave super symmetry intact. The procedure would take into account application of algorithm of super field calculations of the effective potential with results known in the literature.

The emphasis being first towards construction of deformed susy and subsequently calculating effective potential of simplest super-fields. If we start with the deformation of SUSY generators in 3+1 dimensions, the modified susy generators relates lorentz group to SL (2R) which are covariant in three dimensional space time with spinor representations acting on Majorana two component spinor and hence spinor susy generators are Hermitian. To extend normal space to deformed superspace we define the deformed super symmetry genera- tors as those which is basically the derivative with respect to the Grassmannian super space coordinates also a covariantized as space-time derivative. Without generalising we can chose to assume an aether vector, we can refer to this algebra as to the aether-like generalization of the super symmetry algebra, and denominate the theories constructed on its base as the ether-like super field super-symmetric Lorentz-breaking theories which are also not invariant.

There is a simple way to construct derivatives that are invariant under super symmetric transformations generated and which are covariant under Lorentz, chiral, and isospin rotations. Thus from the discussion above, we can say infer that mechanisms and modified algebra which encompass lorentz violating theories is very rich both in scope and application in relation to different theories of high energy physics which may be lorentz violating in character.

References

[1] N. Arkani-Hamed, H. -C. Cheng, M. A. Luty, S. Mukohyama, JHEP 0405, 074 (2004).
[2] S. L. Dubovsky, JHEP 0410, 076 (2004).
[3] Nicolis, R. Rattazzi, E. Trincherini, Phys. Rev. D79, 064036 (2009). [arXiv:0811.2197
[4] F. Farias, A. C. Lehum, J. R. Nascimento and A. Yu. Petrov, Phys. Rev. D 86, 065035 (2012)
[5] S. M. Carroll, H. Tam, Phys. Rev. D78, 044047 (2008), arXiv: 0802.0521; M. Gomes, J. R. Nascimento.
[6] W. Bietenholz, Phys. Rep. 505, 145 (2011), arXiv: 0806.3713 H. Belich, J.
[7] L. Boldo, L. P. Colatto, J. A. Helayel- Neto, A. L. M. A. Nogueira, Phys.Rev.D68, 065030
[8] L. Buchbinder, S. M. Kuzenko, J. V. Yarevskaya, Nucl. Phys. B411, 665 (1994);
[9] L. Buchbinder, S. M. Kuzenko, A. Yu. Petrov, Phys. Lett. B321, 372 (1994 B. de Wit, M. T. Grisaru, M. Rocek, Phys. Lett. B 374, 297 (1996), hep-th/9601115;
[10] Pickering, P. West, Phys. Lett. B 383, 54 (1996), hep-th/9604147; M. T. Grisaru, M. Rocek, R. von Unge, Phys. Lett. B 383, 415 (1996),