RADIATION SYMMETRY AS A SIGNATURE OF SUPERSYMMETRIC GAUGE THEORIES

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Radiation symmetry [1] is a distinctive feature of gauge theories that have any derivative couplings belonging to a highly restrictive class that includes the known renormalizable models. This symmetry follows from the radiation theorem [2] the basis of which is the fact that the emission/absorption (em/ab) of a gauge vector boson can be described as a first-order Poincaré transformation of the associated leg in the given Feynman diagram. For tree graphs there is a kinematic region (the null zone) where all these transformations refer to the same parameter and thus, by invariance, cancel completely. The connection with transformations suggests an analogous relationship between a super gauge field and a combination of Poincaré and supersymmetry (SUSY) transformations, implying an extension of radiation symmetry to include gauge fermions. Indeed Barger et al. [3] find that $q\bar{q}' \to W\gamma$ and $q\bar{q}' \to \tilde{W}\tilde{\gamma}$ have identical null zones, while Robinett [4] has calculated a subset of photino ($\tilde{\gamma}$) amplitudes for a class of scalar-spinor vertices, also obtaining the same null zone as in the corresponding photon (γ) case.

It is important to have a general argument for the relationship between gaugeon and gaugino radiation zeros, thereby establishing criteria for such zeros in SUSY amplitudes, and to determine the mechanism for the intricate cancellations that are seen in [3,4] as well as in somewhat more complex examples. In contrast to the γ case, e.g., there is no single source graph to which a $\tilde{\gamma}$ can be attached in all possible ways in generating the complete amplitude, which complicates the tree-graph analysis, and there are new questions about derivative couplings, gaugino exchange, and gauge-sector quadrilinear couplings. In response, we have found an extended radiation theorem, its proof, and a tree-graph analysis where a relationship between gaugino couplings and SUSY transformations is exhibited [5].

<u>Theorem</u>: In a gauge theory with global (rigid) SUSY (all spins ≤ 1) where any derivative coupling present is minimal [2], all tree-approximated amplitudes for gaugino em/ab have the same radiation zeros as those for gaugeon em/ab.

<u>Proof</u>: Define the Majorana spinor Q^f to be the conserved, translationally invariant fermionic charge that generates rigid SUSY transformations, so that

$$[\bar{\alpha}\, Q^f, S] = 0 \quad , \qquad (1)$$

where S is the scattering operator and α is an arbitrary c-number anti-commuting Majorana spinor. The action of $\bar{\alpha}\, Q^f$ on the scattering <u>in</u> and <u>out</u> states is calculated using the on-shell SUSY algebra (no auxilary fields). Taking the matrix element of (1) between two <u>in</u> (or <u>out</u>) states that differ by one fermionic unit, with a photon in one of them, we infer that

$$\langle a_1, a_2 \ldots |S| b_1, b_2 \ldots \tilde{\gamma}\rangle = \sum \{A_i \langle \tilde{a}_1 \ldots a_1 \ldots |S| b_1 \ldots \gamma\rangle - B_j \langle a_1 \ldots |S| b_1 \ldots \tilde{b}_j \ldots \gamma\rangle\}, \quad (2)$$

where A_i, B_j may be momentum dependent and the Q^f conjugates $\tilde{a}$, $\tilde{b}$ are (possibly summed) in respective supermultiplets of a,b. On-shell, a γ is transformed into a $\tilde{\gamma}$. Each matrix element in (2) has the same set of momenta $\{p_i, q\}$ and charges $\{Q_i\}$. All amplitudes on the right of (2) possess the tree null zone [2]:

$$(Q_i/p_i \cdot q) = \text{same, all } i \quad , \qquad (3)$$

so the tree approximation for the left-hand-side also vanishes under (3). Thus, both types of tree amplitude are symmetric under $Q_i \to Q_i + (\text{cont.})\, p_i \cdot q$, which is the statement of radiation symmetry.

<u>Corollary</u>: The radiation representation [2], and the charge and current sum rules of [1,2] have analogs for $\tilde{\gamma}$ em/ab amplitudes.

<u>Tree graph analysis</u>: Examples of tree amplitudes for $\tilde{\gamma}$ em/ab in the SUSY-QED Wess-Zumino [6] model, L_{WZ}, illustrate a connection between cancellation among different graphs in the null zone and those in $\delta L_{WZ} = \partial^\mu (\ldots)_\mu$ and, in particular, between $\tilde{\gamma}$ attachments and the variations $\delta\phi_i = [\bar{\alpha}\, Q^f, \phi_i]$ of the supermultiplet fields ϕ_i. The $\tilde{\gamma}$ attachments in the L_{WZ} model as well as in an extension that includes a charged vector and its spinor partner involve a combination of SUSY and Poincaré transformations. For instance, $\tilde{\gamma}$ attachments involve the external-leg (momentum p) modifications for a (formerly) outgoing scalar and fermion:

$$1 \to \bar{u}(p)\alpha_1 \text{ and } \bar{u}(p) \to \bar{\alpha}_2(-\not{p}) \quad ,$$

$$\alpha_1 = -(iQ/2p\cdot q)\, v(q) \text{ and } \bar{\alpha}_2 = -(iQ/2p\cdot q)\bar{u}(q).$$

The incoming vector (polarization η) and fermion legs are converted by $\tilde{\gamma}$ attachment according to

$$\eta^\mu \to i\bar{u}(p)\,\gamma^\mu\alpha_1 \text{ and } u(p) \to i(\tfrac{1}{2}[\not{p},\not{\eta}] - 2\, q\cdot\eta)\alpha_1 \ .$$

Armed with super radiation symmetry, reactions such as $\tilde{q}\bar{q}' \to q\bar{q}'\tilde{\gamma}$ in the high-energy limit, where all the masses can be neglected, can be studied phenomenologically in parallel to the analogous photon reactions analyzed for collider experiments [7]. Since the recent observations of large missing transverse energy at the $Sp\bar{p}S$ [8] may be evidence for new physics such as SUSY, the sensitivity of szeros to SUSY-breaking parameters may be especially interesting.

A superfield reformulation, higher-order terms appearing in the variations, and an extension of the all-orders covering theorem [2] are reported elsewhere [5]. This work was supported in part by the National Science Foundation.

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