PROBING HIGH ENERGY PROPERTY OF STRING SCATTERING BY EFFECTIVE FIELD THEORY

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It is known that infinitely many linear relations among string scattering amplitudes appear in high energy limit. These linear relations would imply a symmetry structure that is not manifest before taking the high energy limit. Motivated by this observation, we study an effective field theory of massive spin-2 and spin-1 particles, and try to understand what kind of structure reproduces the linear relations among the amplitudes of bosonic open string.

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Some years ago, appearance of infinity many linear relations among string scattering amplitudes in high energy limit was found in bosonic open string theory.^{1,2} Later, linear relations for the tree level 4-point amplitudes that include higher string excited modes (we denote them as h) and three tachyons (denote as T) were solved.³ It shows that, if we fix mass level of h , then all the leading order amplitudes are proportional to each other. This simplification was speculated as a sign that indicates some hidden symmetry which becomes manifest in high energy limit as proposed by Gross.⁴ Motivated by this observation, we examine an effective field theory which is constructed to reproduce the high energy linear relations among amplitudes found in open bosonic string theory. It is expected to be a useful tool to consider symmetric structure, if there exists.

To study the subject in the simplest setting, we specify mass level of h as $m^2 = 1/\alpha'$. In this case, h are second rank symmetric tensor state $\alpha_{-1}^\mu \alpha_{-1}^\nu |0\rangle$ and vector state $\alpha_{-2}^\mu |0\rangle$. The high-energy linear relation gives a proportional relation

$$M_{LL} : M_{TT} : M_L = 4 : 1 : -\sqrt{2}, \quad (1)$$

where $M_{\mu\nu}$ and M_μ are the tree-level $hT \rightarrow TT$ scattering amplitudes with h being $\alpha_{-1}^\mu \alpha_{-1}^\nu |0\rangle$ and $\alpha_{-2}^\mu |0\rangle$ respectively, and L and T denotes longitudinal and transverse directions of polarization tensors of h . Now we ask a question; what kind of effective Lagrangian reproduces the proportional relation (1)? To construct such an effective field theory, we take special care about the following points:

- String scattering amplitude includes infinite number of pole singularities that correspond to the resonances of intermediate massive string excitations. Therefore we try to reproduce the relation (1) in the level of pole residues of the amplitudes, rather than the amplitudes themselves. Here the pole is taken to be $\alpha's = 1$ (s is the one of Mandelstam variable). This strategy allows us to construct the effective theories with finite number of terms only.
- To have correct degrees of freedom for massive spin particles, we borrow Witten's cubic string field theory⁵ to write down free part of the Lagrangian.
- We work in a sort of derivative truncation scheme to reduce number of interaction vertices, which are relevant to calculating $hT \rightarrow TT$ amplitudes, to finite one. We restrict the number of derivative in these vertices is less than 4. To give some, but not complete, justification of our rule, we refer to a work.⁶

Relation (1) gives ten constraints among couplings in the effective theory. Solving these constraints will give us some insight about the string symmetry in high energy limit. We are also studying pattern of amplitudes in terms of DDF states that will be useful to classify the high energy behaviors of the amplitudes. We hope to report their implications by another publication⁷ in near future.

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