行政院國家科學委員會補助專題研究計畫成果報告

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※　超弦論的超對稱、D-膜型態及 R-R 荷　　　　　　　　　　※
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中文摘要

本計劃我們計算型二弦的 R-R 零規範態.我們發現爲了得到正確的 R-R 荷, 吾人須引進 T-對偶的開弦, 即 D-箔態. 我們亦證明二 B 弦的 SL(2, 2) S-對偶對稱與 R-R 及 NS-NS 零規範態有關.

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Abstract

We calculate the R-R zero-norm states of type II string spectrum. To fit these states into the right symmetry charge parameters of the gauge transformations of the R-R tensor forms, one is forced to T-dualize some type I open string space-time coordinates and thus to introduce D-branes into the theory. We also demonstrate that the constant T-dual R-R 0-form zero-norm state, together with the NS-NS singlet zero-norm state are responsible for the SL(2,Z) S-duality symmetry of the type II B string theory.

It has been pointed out for a long time that the complete space-time symmetry [1] of string theory is related to the zero-norm state (a physical state that is orthogonal to all physical states including itself) in the old covariant quantization of the string spectrum. [2] This observation had made it possible to explicitly construct many stringy ($\alpha' \to \infty$) massive symmetry of the theory. This includes the w_∞ symmetry of the toy 2D string [3] and the *discrete* massless and massive T-duality symmetry of closed bosonic string. [4] The authors of [5] show that, in string theory, some target space mirror symmetry of N=2 backgrounds on group manifolds is a Kac-Moody gaugy symmetry. Thus, like T-duality, it should be related to the zero-norm states. On the other hand, the massless and massive SUSY, and some new enlarged spacetime boson-fermion symmetries induced by zero-norm states were also discussed in [6]. It is thus of interest to study the R-R zero-norm state and its relation to D-brane which was recently shown by Polchinski to be the symmetry charge carrier of the propagating R-R forms. [7]

Presumably, there should be no R-R zero-norm state in the type II string spectrum since the fundamental string does not interact with the R-R forms. However, to our surprise, it was discovered that there do exist both massless and massive R-R zero-norm states in the type II string spectrum. [6] It was then realized that the degree of freedom of massless R-R zero-norm states does not fit into that of the symmetry parameters of the propagating R-R forms and thus resolved the seeming inconsistency. This observation gives us another justification of the well-known wisdom that perturbative string does not carry the massless R-R charges, although the existence of these R-R zero-norm states remain mysterious.

In this paper, we will show that the T-dual R-R zero-norm states serve as the right symmetry parameters of the gauge transformations of the R-R propagating forms. Also one is forced to introduce Type I open string and D-branes into the type II string theory to incorporate these T-dual R-R zero-norm states. Our *spacetime* zero-norm state here is in complementary with the *worldsheet* string vertex operator argument first

by Bianchi, Pradisi and Sagnotti. [3] They considered R-R one-point function in the $(-\frac{1}{2}, -\frac{3}{2})$ ghost picture on the *disk* and resulted in a conclusion which was consistent with D-brane as R-R charge carrier [7]. As an important application, we demonstrate that the constant T-dual R-R 0-form zero-norm state, together with the NS-NS singlet zero-norm state which was always neglected in the previous discussions, are responsible for the *discrete* SL(2,Z) S-duality symmetry of the type II B string theory. [9] This discovery suggests that not only stringy ($\alpha' \to \infty$) symmetry but also strong-weak ($g_s \to \infty$) duality symmetry are related to the existence of zero-norm states of the spectrum.

T-dual R-R zero-norm states motivate the introduction of D-branes into Type II string theory. They serve as symmetry charge parameters of R-R tensor forms. The study in this paper reveals again that all space-time symmetries, including the *discrete* T-duality and S-duality, are related to the zero-norm states in the spectrum. The unified description of S and T dualities makes one to speculate that they are all geometric symmetries (due to the redefinition of string backgrounds) and to conjecture the existence of a bigger discrete U-duality symmetry [9], [17] and its relation to the zero-norm state. In fact the SL(2,Z) S-duality of II B string led Vafa [18] to propose a 12d F-theory, where τ is the geometric complex structure modulus of torus T^2. One can even generalize this zero-norm state idea to construct new stringy massive symmetries of string theory. In particular, the existence of some massive R-R zero-norm states and other evidences make us speculate that string may carry some massive R-R charges [6]. Another interesting issue is the identification of D-brane charges with elements of K-theory groups. [19] How T-dual R-R zero-norm states relate to K-theory groups is an interesting question to study.

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