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Resistance of a rotating-moving brane with background fields against collapse

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HIGHLIGHTS

- We construct the boundary state corresponding to a dynamical D*p*-brane.
- The brane moves and rotates within its volume.
- There are various background fields on the brane.
- We study effect of tachyon condensation on a rotating-moving D*p*-brane.
- Some specific rotations and/or motions can preserve the brane from instability.

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ABSTRACT

Using the boundary state formalism we investigate the effect of tachyon condensation process on a rotating and moving D*p*-brane with various background fields in the bosonic string theory. The rotation and motion are inside the brane volume. We demonstrate that some specific rotations and/or motions can preserve the brane from instability and collapse.

1. Introduction

Some significant steps have been made to study the D-branes as essential objects in the string theory and some of their specifications such as stability [1,2]. The instability of the branes can be studied by the open string tachyon dynamics and tachyon condensation phenomenon [3]. The unstable D-branes decay into the closed string vacuum or to some lower dimensional unstable branes as intermediate states [4–6]. These intermediate states also decay to lower dimensional stable

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configurations or to the closed string vacuum. These concepts have been studied by various methods, e.g. the string field theory [4,7,8].

On the other hand, there is the boundary state method for describing D-branes [9–16]. This method is an applicable tool in many complicated situations. Thus, this valuable formalism can be applied for investigating the tachyon condensation process [17–20]. For example, the boundary state is a source for closed strings, therefore, by using this state and the tachyon condensation, one can find the time evolution of the source. In addition, it has been argued that the boundary state description of the rolling tachyon is valid during the finite time which is determined by the string coupling, and the energy of the system could be dissipated to the bulk beyond this time [19]. Besides, this method elucidates the decoupling of the open string modes at the non-perturbative minima of the tachyon potential [21].

In this article we consider a rotating and moving Dp-brane in the presence of a $U(1)$ gauge potential in the worldvolume of the brane and a tachyon field. The rotation and linear motion of the brane will be considered in its volume. Presence of the above background fields indicates some preferred alignments within the brane. Thus, we shall demonstrate that the Lorentz symmetry on the worldvolume of the brane has been broken, and hence such rotations and motions are sensible. The boundary state corresponding to this non-stationary Dp-brane enables us to investigate the tachyon condensation for gaining a new understanding of this phenomenon on the D-branes. In fact, we shall observe that condensation of tachyon cannot always impel the brane to be unstable. In other words, by considering a rotating-moving brane, the reduction of the brane dimension sometimes does not occur, and hence in spite of the tachyon condensation process we have a stable brane.

This paper is organized as follows. In Section 2, the boundary state corresponding to a dynamical Dp-brane with various background fields (in the context of the bosonic string theory) will be constructed. In Section 3, stability of this D-brane under the condensation of the tachyon will be investigated. Section 4 is devoted to the conclusions.

2. The boundary state of the brane

As we know open strings live on the D-branes. This elucidates that the corresponding fields of the open string states, such as the gauge potential $A_\alpha(X)$ and the tachyon field $T(X)$, exist on the worldvolume of a Dp-brane. Since the boundary of the emitted (absorbed) closed string worldsheet sits on the brane, the closed string possesses some interactions with the open string fields. In other words, the open string fields naturally behave as backgrounds for any closed string which is emitted (absorbed) by the brane. However, in various papers the open string fields $A_\alpha(X)$ and $T(X)$ have been extremely applied as valuable backgrounds for studying the closed strings, e.g. see Refs. [4,8,16–23].

For constructing the boundary state associated with a non-stationary Dp-brane in the presence of the above background fields, we start with the action

$$S = -\frac{1}{4\pi\alpha'}\int_\Sigma d^2\sigma\sqrt{-h}h^{ab}g_{\mu\nu}\partial_a X^\mu\partial_b X^\nu + \frac{1}{2\pi\alpha'}\int_{\partial\Sigma} d\sigma\left(A_\alpha\partial_\sigma X^\alpha + 2\omega_{\alpha\beta}X^\alpha\partial_\tau X^\beta + T(X^\alpha)\right), \tag{1}$$

where Σ is a closed string worldsheet, emitted (absorbed) by the brane, and $\partial\Sigma$ is its boundary. The set $\{X^\alpha|\alpha = 0, 1, \ldots, p\}$ represents the worldvolume directions and the set $\{X^i|i = p+1, \ldots, d-1\}$ indicates the directions perpendicular to it. This action includes the $U(1)$ gauge potential A_α which lives in the brane worldvolume, a tachyonic field $T(X)$ and a dynamical term. This term has the spacetime angular velocity $\omega_{\alpha\beta}$ for the brane rotation and motion in its volume. The components $\{\omega_{0\bar\alpha}|\bar\alpha = 1, \ldots, p\}$ specify the speed of the brane and the elements $\{\omega_{\bar\alpha\bar\beta}|\bar\alpha,\ \bar\beta = 1, \ldots, p\}$ show its rotation.

Unlike the closed string tachyon and dilaton backgrounds which appear in the bulk of the string action and, because of their couplings with the two-dimensional curvature, break the Weyl symmetry our tachyon belongs to the open string spectrum, hence it specifies a surface term for the string action. Therefore, this tachyon field does not couple to the two-dimensional curvature. This fact enables us