STABLE NON-BPS STATES IN STRING THEORY

hep-th/9803194, 9805019, 9805170

+ WORK IN PROGRESS

SET $\alpha' = 1$  $\kappa = 1$  $C = 1$

Strings 98
Ashoke Sen
During the last few years we have learned a lot about the spectrum of BPS states in string theory.

Many string theories also contain elementary string states which are stable due to charge conservation but not BPS.

Spectrum of these states at weak coupling can be found by perturbative analysis.

In this talk we shall analyze the spectrum of these states at strong coupling.
Example 1: \( SO(32) \) Heterotic String Theory

contains states in the spinor representation of \( SO(32) \) at weak coupling

(non-BPS states)

The lightest state in the spinor representation of \( SO(32) \) must be stable at all values of the coupling

Q. What is the mass of this state at strong coupling?

Answer: \( k g^{1/2} \) → string coupling const. known numerical coefficient
Example 2: A Dirichlet \( \Pi \)-brane on top of an orientifold \( \Pi \)-plane (SO(\(2\)) type)

Classical mass of an open string stretched between the \( D \)-brane and its image vanishes in this limit but the supersymmetric ground state is projected out.

The ground state surviving the projection is massive and non-BPS
This state carries charge under the $SO(2)$ gauge field living on the world-volume of the system.

The lightest state carrying $SO(2)$ charge must be stable for all values of the coupling.

Q. What is the mass of this state in the strong coupling limit?
### Summary of the Results for the Dp-Branes + O6-Plane System

<table>
<thead>
<tr>
<th>p</th>
<th>Mass (in String Metric for $g \gg 1$)</th>
<th>Overall Coefficient (known or unknown)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>$\propto g$</td>
<td>Known</td>
</tr>
<tr>
<td>5</td>
<td>$\propto g^{1/2}$</td>
<td>Known</td>
</tr>
<tr>
<td>4</td>
<td>$\propto g^{1/3}$</td>
<td>Unknown</td>
</tr>
<tr>
<td>3</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

$p \geq 7$: Asymptotic & Not Constant

$p \leq 2$: Charged State Has $\propto$ Self-Energy From $\int d^5 x F_{\mu\nu} F^{\mu\nu}$
Now we turn to Example I

$SO(32)$ spinors in heterotic theory in strong coupling limit

\[ \downarrow \text{dual theory} \]

Weakly coupled Type I

Consider Type I compactified on $S^1$ of large radius $R$

Take a D-string - anti-D-string pair wrapped on $S^3$ (coincident)

$D \xrightarrow{\text{periodic B.C.}} \text{spinor}$

$\bar{D} \xrightarrow{\text{anti-periodic B.C.}} \text{scalar}$

$\Rightarrow \text{a spinor of } SO(32)$
MASS $= 2.2\pi R \cdot T_o \to \infty$ as $R \to \infty$

D-STRING TENSION

We need to take into account the fact that this system has a tachyonic mode.

This gives the following minimum energy config. for $R \gg 1$:

\[ \text{(minimum of } V(T) ) \]

\[ \Rightarrow \text{has finite mass for } R \to \infty \text{ if } V(T_o) + 2T_o \]
\[ V(T_0) + \frac{2\pi g}{\sqrt{g}} T_D = 0 \]

Can be "proved"

Assuming this relation to be true, we get

\[ \text{Mass} = \frac{c}{\sqrt{g}} \]

Numerical constant

Indirect argument

\[ c = \sqrt{\frac{3}{2}} \]

Measured in heterotic metric:

\[ m = k g^{1/2} \]

A numerical const. related to \( c \)

Heterotic coupling
DETERMINATION OF C:

COMPACTIFY TYPE I ON A CIRCLE OF RADIUS R
& TAKE A D-STRING ANTI-D-STRING PAIR WRAPPED ON $S^3$

BOUNDARY CONDITION ON $\mathcal{T}$:

$$\mathcal{T}(x + 2\pi R) = -\mathcal{T}(x)$$

∀ SPINOR OF SO(32),

$$\mathcal{T}(x) = \sum_{n \in \mathbb{Z}} \mathcal{T}^{n+\frac{1}{2}} e^{i \frac{(n+\frac{1}{2}) \cdot x}{R}}$$

∀ EFFECTIVE MASS$^2$ OF $\mathcal{T}^{n+\frac{1}{2}}$:

$$\left(\frac{n+\frac{1}{2}}{a} \right)^2/R^2 - m^2_m = \frac{1}{2}$$

∀ NO TACHYONIC MODE FOR
$$R \leq \frac{1}{16}$$
\[ R > \frac{1}{\sqrt{2}}: \]

\[ V(T_{1/2}) \]

\[ T(0) \]

\[ T_{1/2} \]

2. \[ 2\pi R \cdot T_D > m_{\text{spinor}} \]

Total mass \ D-string tension of \( D_1 + \overline{D_1} \)

\[ R < \frac{1}{\sqrt{2}}: \]

\[ V(T_{1/2}) \]

\[ T_{1/2} \]

2. \[ 2\pi R \cdot T_D < m_{\text{spinor}} \]

\( D_1 + \overline{D_1} \) system is stable
At $R = \frac{1}{\sqrt{2}}$, $T_{\frac{1}{2}}$ is massless mode. In fact, it represents an exactly marginal deformation.

$\Rightarrow V(C_{\frac{1}{2}}) = 0$

$V(C_{\frac{1}{2}})$

$T_{\frac{1}{2}}$

$\Rightarrow \exists 2\pi R\cdot T_D = m_{\text{spinor}}$

$\sqrt{2} \Rightarrow \frac{1}{2\pi \sqrt{g}}$

$\Rightarrow m_{\text{spinor}} = 2\pi \cdot \frac{1}{\sqrt{2}} \cdot \frac{1}{2\pi \sqrt{g}} = \frac{\sqrt{2}}{g}$

$\Rightarrow C = \sqrt{2}$
Caveat:

This derivation assumes that:

\[ M_{\text{spinor}} (R = \infty) = M_{\text{spinor}} (R = \frac{1}{\sqrt{2}}) \]

Can we ignore the interaction between the spinor state and its images at distance \( \sim 2\pi n \cdot \frac{1}{\sqrt{2}} \) ?

We do not have a complete answer but note that:

Gravitational Int. \( \sim \frac{1}{\hbar^2} \cdot \frac{\hbar}{\delta y} \cdot \frac{\hat{2}^2}{\hat{1}} \lesssim \frac{1}{\hat{a}^2} \)

Masses \( \downarrow \)

\[ G_{\text{n}} \]
CONCLUSION:

WE HAVE IDENTIFIED THE SO(32) SPINOR STATE IN TYPE I AND CALCULATED ITS MASS.

Perhaps there is a simpler description of this state as some kind of "D-particle" in type I.

Bergman & Gaboridich

We shall now turn to the Dp-brane + OSp-plane system.