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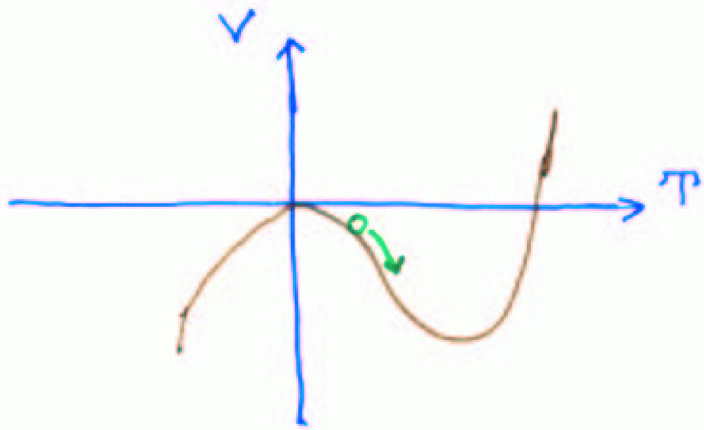
TIME DEPENDENT SOLUTION:

FOCUS ON BOSONIC STRING THEORY FOR DEFINITENESS.



WE WANT TO STUDY SOLUTIONS DESCRIBING ROLLING OF THE TACHYON TOWARDS THE MINIMUM OF THE POTENTIAL

RESULT: THE SYSTEM EVOLVES TO A GAS OF ZERO PRESSURE AS THE TACHYON ROLLS TOWARDS THE MINIMUM OF V(T)

Derivation of these results:

General strategy for studying time dependent solution in any theory:

1. Begin with a static solution that depends on some spatial coordinate x.
2. Replace x by ix^0 where x^0 is the time coordinate.
3. The new configuration is bound to be (formally) a solution of the equations of motion.
4. But there could be problems *e.g.*

   The solution may not be real.

   The solution may hit a singularity.

BEGIN WITH LINEARIZED EQ. OF MOTION:

$$(\partial_0^2 + m^2)\,T = 0$$

$m^2 = -1$ (FOR BOSONIC STRING THEORY)

GIVES:

$$T = A\,e^{x^0} + B\,e^{-x^0}$$

1) $T = \lambda$, $\partial_0 T = 0$ AT $x^0 = 0$ GIVES:

$$T(x^0) \simeq \lambda \cosh(x^0)$$

2) $T = 0$, $\partial_0 T = \lambda$ AT $x^0 = 0$ GIVES

$$T(x^0) \simeq \lambda \sinh(x^0)$$

BOTH SOLUTIONS ARE VALID FOR

$$|\lambda| << 1, \quad x^0 \lesssim 1$$

WE SHALL FOCUS ON THE SOLUTION

$$T(x^0) \simeq \lambda \cosh(x^0)$$

FOR DEFINITENESS

→ CORRESPONDS TO ADDING A BOUNDARY PERTURBATION TO THE CFT:

$$\tilde{\lambda} \int dt \;\; \underbrace{\cosh(x^0(t))}_{\text{DIMENSION 1 OPERATOR}}$$

t: PARAMETER LABELLING THE REAL AXIS OF UPPER HALF PLANE

CAN WE FIND A SOLUTION TO THE FULL EQUATIONS OF MOTION IN STRING FIELD THEORY AS A POWER SERIES IN λ?

WE CAN, IF THE ABOVE BOUNDARY PERTURBATION IS EXACTLY MARGINAL

IS IT EXACTLY MARGINAL?

GO TO THE WICK ROTATED THEORY

$$x^0 \to i X$$

PERTURBATION BECOMES

$$\tilde{\lambda} \int dt \, \cos(X(t))$$

THIS IS KNOWN TO BE AN EXACTLY MARGINAL DEFORMATION

$\Rightarrow$ A SOLUTION OF SFT EQUATIONS OF MOTION

$$\{\phi_r(k)\} \xrightarrow[\text{FOURIER TRS}]{} \{\tilde{\phi}_r(x)\}$$

$\hat{\phi}_r(x^0) \equiv \tilde{\phi}_r(-i x^0)$ IS A SOLUTION OF THE EQS. OF MOTION

ONE CAN CHECK EXPLICITLY THAT $\hat{\phi}_r(x^0)$ IS REAL.

THIS SHOWS THE EXISTENCE OF A FAMILY OF TIME DEPENDENT SOLUTIONS PARAMETRIZED BY $\tilde{\lambda}$.

IN STUDYING PROPERTIES OF THESE SOLUTIONS, IT IS MORE CONVENIENT TO DIRECTLY WORK WITH THE DEFORMED BOUNDARY CFT

Consider the case $T \simeq \lambda \cosh(x^0)$

Corresponds to a bondary deformation by:

$$\boxed{\tilde{\lambda} \int dt \cosh(X^0(t))}$$

$$\boxed{\tilde{\lambda} = \lambda + \mathcal{O}(\lambda^2)}$$

$\tilde{\lambda} > 0$ corresponds to pushing the tachyon in a direction in which the potential has a local minimum.

For $\tilde{\lambda} > 0$, the boundary term is positive definite and hence we might expect the theory to be sensible.

$\tilde{\lambda} < 0$ corresponds to pushing the tachyon in a direction in which the potential is unbounded from below.

For $\tilde{\lambda} < 0$, the boundary term is negative definite and hence we might expect the theory to be sick.

CAN WE SAY SOMETHING MORE QUANTITATIVE FOR THIS BCFT?

e.g. HOW DOES THE ENERGY-MOMENTUM TENSOR $T_{\mu\nu}$ EVOLVE WITH TIME?

STUDY THE BOUNDARY STATE

WE SHALL STUDY THE BOUNDARY STATE IN THE WICK ROTATED THEORY AND THEN MAKE $x \to -ix^0$ REPLACEMENT

BOUNDARY STATE $|B\rangle$ ASSOCIATED WITH A BCFT $\to$ A CLOSED STRING STATE OF GHOST NO. 3

$\langle B|V\rangle$: ONE POINT FUNCTION OF THE CLOSED STRING VERTEX OP. $V(0)$ ON THE UNIT DISK

b.c. APPROPRIATE TO BCFT

$$\langle B|V\rangle = \langle V(0)\rangle_D$$

THE BOUNDARY STATE ASSOCIATED WITH A D-BRANE TELLS US WHAT TYPE OF SOURCE THE D-BRANE IS FOR THE CLOSED STRING FIELD

CLOSED STRING FIELD $|\Psi_c\rangle$:

→ A STATE OF THE FIRST QUANTIZED CLOSED STRING OF GHOST NUMBER 2

LINEARIZED EQ. OF MOTION OF $|\Psi_c\rangle$ IN THE PRESENCE OF A D-BRANE:

$$(Q_B + \bar{Q}_B)\,|\Psi_c\rangle = |B\rangle$$

↳ BOUNDARY STATE

$$|\Psi_c\rangle = \int d^{26}k \left[\tilde{T}_c(k) + \tilde{h}_{\mu\nu}(k)\, \alpha^{\mu}_{-1} \bar{\alpha}^{\nu}_{-1} + \cdots\cdots \right] c_1 \bar{c}_1 |k\rangle$$

GRAVITON

CLOSED STRING TACHYON

$$c(z) = \sum c_n z^{-n+1}, \quad \bar{c}(\bar{z}) = \sum \bar{c}_n \bar{z}^{-n+1}$$

$$X^{\mu}(z,\bar{z}) = x^{\mu} + p^{\mu} \ln z\bar{z} + \sum_{n\neq 0} \left(\frac{\alpha^{\mu}_n}{n} z^{-n} + \frac{\bar{\alpha}^{\mu}_n}{n} \bar{z}^{-n} \right)$$

SINCE $|B\rangle$ CONTAINS SOURCE TERM FOR $h_{\mu\nu}$, IT HAS INFORMATION ABOUT ENERGY MOMENTUM TENSOR $T_{\mu\nu}$

GENERAL FORM OF $|B\rangle$:

$$|B\rangle = \int d^{26}k \left[\tilde{\mathcal{F}}(k) + \tilde{A}_{\mu\nu}(k)\, \alpha^{\mu}_{-1} \bar{\alpha}^{\nu}_{-1} + \tilde{B}(k) \left(b_{-1} \bar{c}_{-1} + \bar{b}_{-1} c_{-1} \right) + \cdots \right] (c_0 + \bar{c}_0)\, c_1 \bar{c}_1 |k\rangle$$

CLOSED STRING FIELD EQ.

$\rightarrow$ EQ. RELATING $h_{\mu\nu}$ WITH $A_{\mu\nu}$ & B

$\rightarrow$ CAN BE COMPARED WITH LINEARIZED EINSTEIN'S EQ. TO COMPUTE THE $T_{\mu\nu}$.

A DIFFERENT METHOD:

WE NEED $(Q_B + \bar{Q}_B)|B\rangle = 0$

$$\Rightarrow k^{\nu} \left(\tilde{A}_{\mu\nu} + \eta_{\mu\nu} \tilde{B} \right) = 0 \Rightarrow \partial^{\mu} \left(A_{\mu\nu} + \eta_{\mu\nu} B \right) = 0$$

$$\Downarrow$$

$$\Rightarrow T_{\mu\nu} = A_{\mu\nu} + \eta_{\mu\nu} B \qquad \partial^{\mu} T_{\mu\nu} = 0$$

THE BOUNDARY STATE IN THE WICK ROTATED THEORY CAN BE COMPUTED

(Recknagel, Schomerus)

WORLD-SHEET ACTION

$$\frac{1}{4\pi}\int d^2z\,[\partial_z X\ \partial_{\bar z} X] + \tilde\lambda \int dt\ \cos(X(t))$$

$$+ \ \cdots\cdots\cdots$$

$\hookrightarrow$ 25 OTHER SCALAR FIELDS

RESULT:

$$T_{00}(x) = -\frac{1}{2}\tau_p\,(1+\cos(2\tilde\lambda\pi))$$

$$T_{0i} = 0, \qquad T_{ij} = -\tau_p\,\hat f(x)\,\delta_{ij}$$

$$\hat f(x) = 1 + \sum_{n=1}^{\infty}(-1)^n(\sin\tilde\lambda\pi)^n\{e^{inx} + e^{-inx}\}$$

WICK ROTATE : $x = -ix^0$

$$\hat f(-ix^0) = 1 + \sum_{n=1}^{\infty}(-1)^n(\sin\tilde\lambda\pi)^n(e^{nx^0} + e^{-nx^0})$$

$$f(x^0) = \frac{1}{1+e^{x^0}\sin\tilde\lambda\pi} + \frac{1}{1+e^{-x^0}\sin\tilde\lambda\pi} - 1$$

$\rightarrow$ GIVES THE RESULT QUOTED EARLIER

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$$f(x^0) = \frac{1}{1+e^{x^0}\sin\tilde{\lambda}\pi} + \frac{1}{1+e^{-x^0}\sin\tilde{\lambda}\pi} - 1$$

AS $x^0 \to \infty$, $f(x^0) \to 0$

THE SYSTEM EVOLVES TO A PRESSURELESS GAS

CASE OF PERTURBATION BY

$$\tilde{\lambda}\int dt \, \sinh(X^0(t))$$

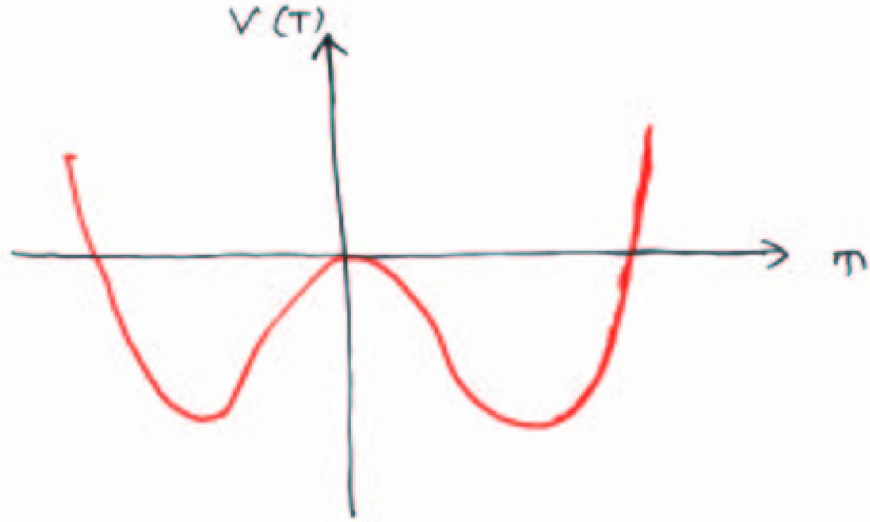
→ RELATED TO THE PREVIOUS CASE BY

$$X^0 \to X^0 + i\pi, \quad \tilde{\lambda} \to -i\tilde{\lambda}$$

$$\Rightarrow \quad f(x^0) = \frac{1}{1+e^{x^0}\sinh(\tilde{\lambda}\pi)} + \frac{1}{1-e^{-x^0}\sinh(\tilde{\lambda}\pi)} - 1$$

$$T_{00} = \tau_p\left(1+\cosh(2\tilde{\lambda}\pi)\right)$$

SIMILAR RESULTS HOLD FOR UNSTABLE D-BRANES / $D\bar{D}$ SYSTEMS IN SUPERSTRING THEORY



Begin with the linearized equations of motion:

$$\boxed{(\partial_0^2 + m^2)T = 0}$$

$\boxed{m^2 = -1/2}$

Gives

$$\boxed{T = Ae^{x^0/\sqrt{2}} + Be^{-x^0/\sqrt{2}}}$$

1) $T = \lambda$, $\partial_0 T = 0$ at $x^0 = 0$ gives

$$\boxed{T(x^0) = \lambda \cosh(x^0/\sqrt{2})}$$

2) $T = 0$, $\partial_0 T = \lambda/\sqrt{2}$ at $x^0 = 0$ gives

$$\boxed{T(x^0) = \lambda \sinh(x^0/\sqrt{2})}$$

We shall focus on the solution

$$\boxed{T(x^0) \sim \lambda \cosh(x^0/\sqrt{2})}$$

→ corresponds to adding a boundary perturbation to the CFT

$$\boxed{\tilde{\lambda} \int dt \, [\psi^0 \sinh(X^0/\sqrt{2})]_{boundary} \otimes \sigma_1}$$

Open string world-sheet

$$\boxed{\tilde{\lambda} = \lambda + \mathcal{O}(\lambda^2)}$$

ψ^0: world-sheet superpartner of x^0

σ_1: Chan-Paton factor

Can we find a solution to the full set of equations of motion in string field theory as a power series in λ?

We can, if the above boundary perturbation is exactly marginal.

Is it exactly marginal?

Go to the Wick rotated theory

$$\boxed{X^0 \to iX,\ \psi^0 \to i\psi}$$

Perturbation becomes

$$\boxed{\tilde{\lambda} \int dt\, [\psi \sin(X/\sqrt{2})]_{boundary} \otimes \sigma_1}$$

This is known to be an exactly marginal deformation via fermionization of X A.S.

On the boundary:

$$\boxed{e^{iX/\sqrt{2}} \sim (\xi + i\eta)}$$

ξ, η are Majorana fermions.

Thus perturbation becomes proportional to:

$$\boxed{\tilde{\lambda} \int dt\, [\psi\eta]_{boundary} \otimes \sigma_1}$$

$\to$ a solvable CFT

98e

The relevant part of the boundary state for computation of $T_{\mu\nu}$:

$$\boxed{\begin{aligned} |\mathcal{B}_0\rangle \;\propto\; & \Big[\psi^{\mu}_{-1/2}\bar{\psi}^{\nu}_{-1/2}A_{\mu\nu}(X^0(0)) \\ & + (\bar{\beta}_{-1/2}\gamma_{-1/2} - \beta_{-1/2}\bar{\gamma}_{-1/2})B(X^0(0))\Big]|\Omega\rangle\,, \end{aligned}}$$

β, γ: bosonic superconformal ghosts

$|\Omega\rangle$: the ghost number 3, picture number -2 vacuum

$$\boxed{|\Omega\rangle = (c_0 + \bar{c}_0)c_1\bar{c}_1 e^{-\phi(0)}e^{-\bar{\phi}(0)}|0\rangle}$$

ϕ: bosonized ghost

Energy momentum tensor:

$$\boxed{T_{\mu\nu}(x^0) = A_{\mu\nu}(x^0) + B(x^0)\eta_{\mu\nu}}$$

(Follows from the requirement that $(\bar{K}_0 + Q_B)|\mathcal{B}_0\rangle = 0$ should reproduce $\partial^{\mu}T_{\mu\nu} = 0$)

Results for $A_{\mu\nu}$ and B can be obtained by picking up the appropriate terms in the boundary state of the Wick rotated theory and then performing an inverse Wick rotation.

Result: (Following Recknagel, Schomerus; Recknagel, Gaberdiel,

$$A_{00} = g(x^0), \quad A_{ij} = -f(x^0)\delta_{ij}, \quad B = -f(x^0)$$

$$g(x^0) = 1 + \cos(2\pi\tilde{\lambda}) - f(x^0)$$

$$\begin{aligned} f(x^0) &= 1 + \sum_{n=1}^{\infty} (-1)^n \sin^{2n}(\tilde{\lambda}\pi) \\ &\qquad \times (e^{n\sqrt{2}x^0} + e^{-n\sqrt{2}x^0}) \\ &= \frac{1}{1 + e^{\sqrt{2}x^0}\sin^2(\tilde{\lambda}\pi)} \\ &\qquad + \frac{1}{1 + e^{-\sqrt{2}x^0}\sin^2(\tilde{\lambda}\pi)} - 1\,. \end{aligned}$$

(Note: $e^{n\sqrt{2}x^0}$ comes from inverse Wick rotation of $e^{in\sqrt{2}x}$)

$e^{in\sqrt{2}\,x(0)}|0\rangle = |k = n\sqrt{2}\rangle$

This gives us back the answer quoted earlier.

The result for $T(x^0) \sim \lambda \sinh(x^0/\sqrt{2})$ can be obtained by the replacement

$$\boxed{\lambda \to -i\lambda, \quad x^0 \to x^0 + i\pi/\sqrt{2}}$$

Raslelli, A.S., Zwieb
w/ Giotto
Gross, Taylor
⋮

Vacuum string field theory (VSFT)

Suppose $|\Phi_0\rangle$ denotes the tachyon vacuum solution

$$\boxed{|\Psi\rangle \equiv |\Phi\rangle - |\Phi_0\rangle \in \mathcal{H}_1}$$

$$\boxed{S(|\Phi\rangle) = S(|\Phi_0\rangle) + \widetilde{S}(|\Psi\rangle)}$$

$$\boxed{\widetilde{S}(|\Psi\rangle) = -\frac{1}{g^2}[\frac{1}{2}\langle\Psi|\mathcal{Q}|\Psi\rangle + \frac{1}{3}\langle\Psi|\Psi * \Psi\rangle]}$$

$$\boxed{\mathcal{Q}|A\rangle \equiv Q_B|A\rangle + |\Phi_0\rangle * |A\rangle \cancel{+} (-1)^{n_A}|A\rangle * |\Phi_0\rangle}$$

$\mathcal{Q}$ satisfies a set of identities (E):

1) $\mathcal{Q}^2 = 0$

2) $\langle \mathcal{Q}A|B\rangle = (-1)^{n_A}\langle A|\mathcal{Q}|B\rangle$

3) $\mathcal{Q}(|A\rangle * |B\rangle) = (\mathcal{Q}|A\rangle) * |B\rangle + (-1)^{n_A}|A\rangle * (\mathcal{Q}|B\rangle)$

→ guarantees gauge invariance of $\widetilde{S}(|\Psi\rangle)$.

Conjecture 2: $\mathcal{Q}$ has vanishing cohomology

At present we know the form of $|\Phi_0\rangle$ and hence of $\mathcal{Q}$ only numerically.

Strategy: Try to guess the form of $\mathcal{Q}$ which satisfies all the requirements.

Proposal: It is possible, via an appropriate field redefinition which leaves the cubic coupling unchanged, to bring $\mathcal{Q}$ into a form made purely of ghost fields.

Insight: beginning with any BCFT, we should end up in the same vacuum.

(vacuum without any D-brane)

Thus SFT around the tachyon vacuum should be insensitive to the choice of initial BCFT.

$\mathcal{Q}$ being made of ghosts $\rightarrow$ independent of the choice of BCFT.

Note however that $|\Psi\rangle \in \mathcal{H}_1$, – the vector space of states of BCFT.

→ there is still some implicit dependence on BCFT.

All physical results should be independent of the choice of BCFT (need to be shown)

Is there a choice of $\mathcal{Q}$ which is made purely of ghosts, satisfies the required identities E, and has vanishing cohomology?

Yes.

$$\boxed{\mathcal{Q} = \sum_n a_n(c_n + (-1)^n c_{-n})}$$

a_n: arbitrary coefficients.

Each of these $\mathcal{Q}$ satisfies the identities E.

What about the cohomology of $\mathcal{Q}$?

Suppose $a_m \neq 0$ for some m.

Define $\boxed{\mathcal{B} = \frac{1}{2} a_m^{-1}(b_m + (-1)^m b_{-m})}$

Then $\boxed{\{\mathcal{Q}, \mathcal{B}\} = 1}$

Thus if $\mathcal{Q}|A\rangle = 0$, then $|A\rangle = \mathcal{Q}\mathcal{B}|A\rangle$

$\rightarrow$ any $\mathcal{Q}$-closed state $|A\rangle$ is also $\mathcal{Q}$-exact.

$\rightarrow$ $\mathcal{Q}$ has trivial cohomology.

We now need to verify that:

1. The action

$$\boxed{\tilde{S}(|\Psi\rangle) = -\frac{1}{g^2}\left[\frac{1}{2}\langle\Psi|\mathcal{Q}|\Psi\rangle + \frac{1}{3}\langle\Psi|\Psi * \Psi\rangle\right]}$$

has a classical solution representing the original D-brane associated with $BCFT$.

→ conjecture 1

2. It has classical solution representing any other D-brane in the same space-time background, associated with some other boundary CFT $BCFT'$.

(the lump solutions)

→ Conjecture 3

Equations of motion:

$$\boxed{\mathcal{Q}|\Psi\rangle + |\Psi\rangle * |\Psi\rangle = 0}$$

Look for factorized solution:

$$\boxed{|\Psi\rangle = |\Psi_g\rangle \otimes |\Psi_m\rangle}$$

$g \to$ ghost part, $\quad m \to$ matter part

$$\boxed{\mathcal{Q}|\Psi_g\rangle \otimes |\Psi_m\rangle + |\Psi_g * \Psi_g\rangle \otimes |\Psi_m * \Psi_m\rangle = 0}$$

This gives

$$\boxed{\mathcal{Q}|\Psi_g\rangle + \mathcal{N}|\Psi_g * \Psi_g\rangle = 0}$$

$$\boxed{|\Psi_m * \Psi_m\rangle = \mathcal{N}|\Psi_m\rangle}$$

$\mathcal{N}$: arbitrary normalization constant

For such a solution the value of the action is

$$\boxed{\widetilde{S}(|\Psi\rangle) = -\frac{1}{6g^2}\langle\Psi_g|\mathcal{Q}|\Psi_g\rangle\,\langle\Psi_m|\Psi_m\rangle}$$

Universality ansatz: different D-branes are described by the same ghost part $|\Psi_g\rangle$ but by different matter parts $|\Psi_m\rangle$.

$BCFT$ D-brane $\rightarrow$ $|\Psi\rangle = |\Psi_g\rangle \otimes |\Psi_m\rangle$

$BCFT'$ D-brane $\rightarrow$ $|\Psi\rangle = |\Psi_g\rangle \otimes |\Psi'_m\rangle$

Note: both $|\Psi_m\rangle$ and $|\Psi'_m\rangle$ belong to the same state space $\mathcal{H}_1$ (of $BCFT$)

Ratio of the D-brane energies:

$$\boxed{\frac{E'}{E} = \frac{\tilde{S}(|\Psi'\rangle)}{\tilde{S}(|\Psi\rangle)} = \frac{\langle\Psi'_m|\Psi'_m\rangle_m}{\langle\Psi_m|\Psi_m\rangle_m}}$$

$\langle A|B\rangle_m$: inner product in the matter sector only

Thus we can compute the ratio E'/E even without knowing the form of $\mathcal{Q}$, and compare with the known ratios of tensions of D-branes.

$$\boxed{|\Psi_m * \Psi_m\rangle = \mathcal{N}|\Psi_m\rangle,} \qquad \boxed{|\Psi'_m * \Psi'_m\rangle = \mathcal{N}|\Psi'_m\rangle}$$

$\rightarrow$ projectors of the $*$-algebra in the matter sector.

Candidate projectors describing different D-branes have been constructed.

Computation of $\langle\Psi'_m|\Psi'_m\rangle_m/\langle\Psi_m|\Psi_m\rangle_m$ gives the correct ratios of energies of different D-branes.

$\rightarrow$ verification of conjectures 1 and 3.

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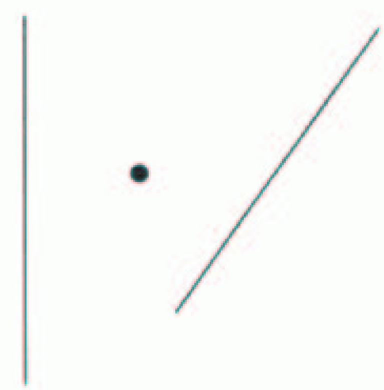
One can also construct solutions representing a configuration of arbitrary number of D-branes at arbitrary positions and orientations.



Strategy: Principle of superposition

If $|\Psi_m\rangle$ and $|\Psi'_m\rangle$ denote two different projectors describing two different D-branes then one can show that

$$\boxed{|\Psi_m * \Psi'_m\rangle = 0,} \qquad \boxed{\langle\Psi_m|\Psi'_m\rangle_m = 0}$$

Thus $\boxed{|\Psi_m\rangle + |\Psi'_m\rangle}$ is also a projector and describes a solution representing the superposition of two D-branes.

This can be generalized to construct superposition of arbitrary number of D-branes.

So far our analysis has been insensitive to the choice of $\mathcal{Q}$.

What is $\mathcal{Q}$?

Strategy for finding $\mathcal{Q}$:

1. Take a general form

$$\boxed{\mathcal{Q} = \sum_{n=0}^{\infty} a_n (c_n + (-1)^n c_{-n})}$$

2. Fix Siegel gauge $b_0|\Psi\rangle = 0$.

The equations of motion in this gauge take the form:

$$\boxed{a_0|\Psi\rangle + b_0|\Psi * \Psi\rangle = 0}$$

3. Then determine $\mathcal{Q}$ by requiring that the solution to the above equation satisfies the full set of equations of motion:

$$\boxed{\mathcal{Q}|\Psi\rangle + |\Psi * \Psi\rangle = 0}$$

It turns out that among the class of operators linear in c_n, the only consistent choice is

$$\boxed{\mathcal{Q} = K[c_0 + \sum_n (-1)^n (c_{2n} + c_{-2n})] = \frac{K}{2i}[c(i) - c(-i)]}$$

K: a normalization constant

We can determine K by requiring that the solution $|\Psi\rangle$ of the form $|\Psi_g\rangle \otimes |\Psi_m\rangle$ representing the original D-p-brane must have

$$\boxed{S(|\Psi\rangle) = -\mathcal{T}_p V_{p+1}}$$

It turns out that in order to satisfy this condition we must have $K = \infty$.

Conclusion: Vacuum string field theory must be related to the original SFT by a singular field redefinition.

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Can we identify what field redefinition relates VSFT to the original SFT?

A complete answer will require the knowledge of the solution $|\Phi_0\rangle$ which represents the tachyon vacuum in the original SFT.

However one can guess the singular part of the field redefinition that is responsible for the singular nature of $\mathcal{Q}$ in VSFT.

Consider a reparametrization of the string that is symmetric about the mid-point.

$\sigma \to f(\sigma)$ with $f(\pi - \sigma) = \pi - f(\sigma)$.

Suppose further that the effect of this reparametrization is to squeeze most of the string to its mid-point.

i.e. $f(\sigma) \simeq \pi/2$ for most of the range of σ.

Under such a reparametrization the coefficient of any negative dimension operator at the mid-point will grow large.

Thus if initially $\mathcal{Q}$ contained a piece of the form

$$\boxed{\int d\sigma g(\sigma) c(\sigma)}$$

for some finite function $g(\sigma)$, then after this reparametrization the dominant contribution to $\mathcal{Q}$ will be of the form

$$\boxed{K(c(i) - c(-i))}$$

with infinite coefficient K.

This mechanism not only explains the origin of the singularity in the VSFT action, but also provides a natural mechanism for obtaining a $\mathcal{Q}$ made of pure ghosts.

Even if to begin with $\mathcal{Q}$ contained matter pieces, after this reparametrization the ghost part involving $c(\pm i)$ gives the dominant contribution.

CONCLUSION

DYNAMICS OF UNSTABLE D-BRANE SYSTEMS IN STRING THEORY EXHIBIT MANY NOVEL FEATURES

FURTHER STUDY OF THIS DYNAMICS IS LIKELY TO IMPROVE OUR UNDERSTANDING OF FORMAL ASPECTS OF STRING THEORY AND ALSO POSSIBLE COSMOLOGICAL ASPECTS OF STRING THEORY.