Instituto de Física Teórica
UAM-CSIC

Dynamical Cobordism via tachyon condensation in supercritical strings

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String Phenomenology 2022

based on ongoing work with Roberta Angius and Angel Uranga

This talk in a nutshell

Dynamical Cobordism describes dynamical realizations of the cobordism conjecture by analysing **spacetime-dependent solutions** that depict **bubbles/walls of nothing** and **interpolating walls** between different QG theories.

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Closed string tachyon condensation in **supercritical linear dilaton backgrounds** has been argued to lead to **bubbles of nothing and dimension-changing bubbles.**

⇒ An explorative effective field theory treatment of tachyon condensation in bosonic string theory allows us to link the two concepts

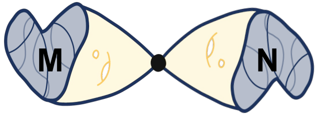
→ put the aforementioned tachyon condensation processes under the dynamical cobordism umbrella.

The plan:

- **Dynamical Cobordism**
  Cobordism from the EFT perspective: walls of nothing and interpolating walls
- **Exact solutions in supercritical string theory**
  linear dilaton background, light-like tachyon, two-derivative effective action
- **Tachyon condensation as stringy cobordisms**
  Bubbles of nothing and dimension-changing bubbles as a realization of dynamical cobordisms

Dynamical Cobordism

A brief overview



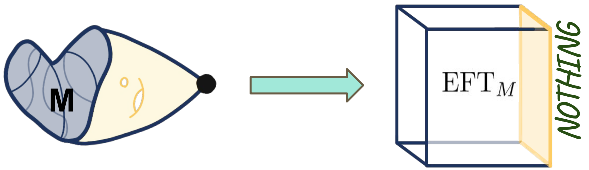
Cobordism

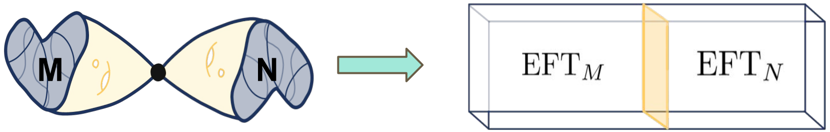
McNamara Vafa 1909.10355

The cobordism conjecture states that all valid QG backgrounds should be trivial in cobordism:

$$\Omega_p^{QG} = 0$$

there is a finite action process that lets you shrink the compact manifold to a point





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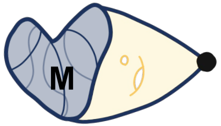
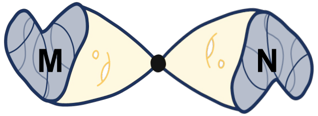
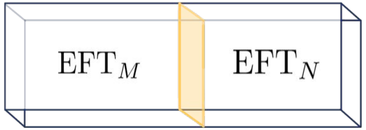






Dynamical Cobordism

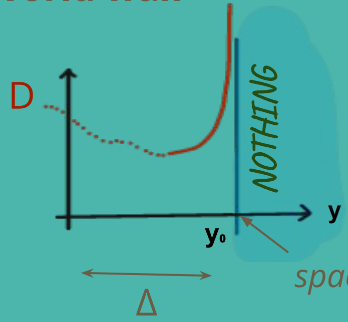
Buratti, Calderon-Infante, Delgado, Uranga
2107.09098

When cobordism happens dynamically along a dimension of spacetime

in the EFT:

End of the World wall

field space distance



$D \to \infty$

spacetime singularity

Scaling Relations

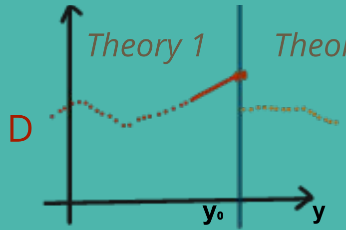
$$\Delta = e^{-\frac{\delta}{2}D}$$

$$|R| = e^{\delta D}$$

$$\delta \sim O(1)$$

Interpolating wall

$D \not\to \infty$



Remarks

Dynamical Cobordism describes the symptoms of a cobordism to nothing from the limited perspective of the EFT

near the singularity:

- loss of control of the EFT
- fully resolved as a cobordism to nothing in the full-fledged UV theory.

More details?
see Roberta Angius and Jesús Huertas' slides, and José Calderón-Infante's talk (theater A at 17h40)

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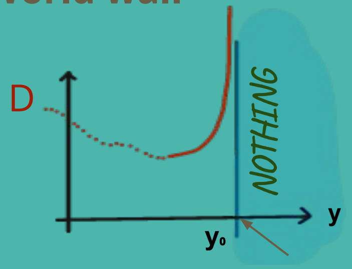

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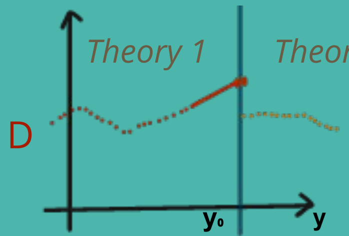

Away from the critical dimension

linear dilaton backgrounds and *tachyons*

Away from the critical dimension

As we know, in flat minkowski spacetime, the vanishing of the beta function of the dilaton leads to imposing:

$$D = D_c$$

However, in the presence of a linear dilaton background, i.e.

$$\Phi(X) = V_\mu X^\mu,$$

the vanishing of the dilaton beta function yields:

$$\frac{D-26}{6} + \alpha' V_\mu V^\mu = 0$$

plus, it's exact in α' and has a weakly-coupled region!

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but what does this mean?

in analogy with the open string case…

the closed string tachyon signals an instability of spacetime itself, and tachyon condensation can lead to the decay of spacetime

In bosonic ST this happens because the tachyon couples to the worldsheet like a **potential.** When $T \to \infty$, no string states can penetrate the potential barrier which results in a "space of nothing".

….sounds exactly like an ETW wall!

Linearized deformation of the supercritical linear dilaton background

EFT description of tachyons is ambiguous because:

- The tachyon potential is unknown
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The strategy is to focus on simple, yet non-trivial class of solution: *Hellerman, Swanson 0611317*

At linear order in conformal perturbation theory, the tachyon is Weyl invariant iff it satisfies the equation:

$$\partial^2 T(X) - 2V^\mu \partial_\mu T(X) + \frac{4}{\alpha'} T(X) = 0$$

focus on the class of solutions: a light-like tachyon in a time-like linear dilaton background:

$$T(X^+) = \mu e^{\beta X^+} \quad V_0 = -q \quad G^{w.s.}_{\mu\nu} = \eta_{\mu\nu}$$

with $\beta = \frac{2\sqrt{2}}{q\alpha'}$ $q = \sqrt{\frac{D-26}{6\alpha'}}$

gs << 1 in the future

This solution is exact in α' and is conformally invariant to all orders of perturbation theory!

Effective action of the graviton+dilaton+tachyon system

Hellerman, Swanson 0611317

Two-derivative action in the sigma-model frame

general form:

$$S = \frac{1}{2\kappa^2}\int d^D x \sqrt{-\mathrm{det} G^{ws}} e^{-2\Phi}[f_1 R + 4 f_2 (d\Phi)^2 - f_3 (dT)^2 - 2V(T) - f_5 (dT d\Phi)]$$

all unknown functions can be expressed in terms of $f_1(T)$

Higher-order corrections

- higher-derivative corrections → 2-derivative action ❔
- gs corrections ✅
- conformal perturbation theory → f_1

Two-derivative action in the Einstein frame with $G^E = e^{\frac{-4\Phi + 2\log f_1}{D-2}} G^{ws}$ and $\Phi = \frac{1}{2}\sqrt{D-2}\phi$

$$S = \frac{1}{2\kappa^2}\int d^D x \sqrt{-G^E}[R^E - (\partial_E \phi)^2 - (\frac{D-1}{D-2}\frac{f_1'^2}{f_1^2} - \frac{f_1''}{f_1} - \frac{f_1'}{f_1 T})(\partial_E T)^2 - \frac{2}{3\alpha'} e^{\frac{2\phi}{\sqrt{D-2}}} f_1^{\frac{-D}{D-2}}((D-26) f_1 + 12 T f_1') + 2\frac{f_1'}{\sqrt{D-2} f_1}\partial_E \phi \partial^E T]$$

Effective action of the graviton+dilaton+tachyon system

Hellerman, Swanson 0611317

Constraints on $f_1(T)$

In order to proceed with the Einstein-frame metric and action, one must first determine a profile for $f_1(T)$.

- One can generally impose some regularity conditions on $f_1(T)$
- These do not fully constrain $f_1(T)$ at large T but an option is given by:

$$f_1(T) = e^{-T^2}$$

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➔ there is a spacetime singularity when $T \longrightarrow \infty$

At fixed time and at leading order in $T \longrightarrow \infty$, we have:

$$\mathcal{D} \sim \frac{T^2}{\sqrt{D-2}} \quad \text{and} \quad \Delta \sim e^{-\frac{|\mathcal{D}|}{\sqrt{D-2}}}$$

We have checked other profiles for $f_1(T)$ compatible with the regularity conditions and we find similar scalings.

Light-like tachyon condensation as a

DYNAMICAL COBORDISM TO NOTHING

➔ From the metric and action we see that there is a spacetime singularity when T$\rightarrow \infty$

➔ the field space distance and spacetime distance respect the scaling relation (at fixed time):

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…briefly… *Hellerman, Swanson 0612051*

now consider a slightly more general setting: dimension-changing bubbles

$$T(X) = \mu_0^2 e^{\beta X^+} - \mu_k^2 \cos(k X_2) e^{\beta_k X^+}$$

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From the world sheet perspective, expanding around X_2=0 with 1/k >> ls, this can be shown to reduce to:

$$T(X) \sim \frac{\mu^2}{2\alpha'} e^{\beta X^+} : X_2^2 : + \frac{\mu^2 X^+}{\alpha' q\sqrt{2}} e^{\beta X^+} + \mu'^2 e^{\beta X^+}$$

The strings at late times are confined to the region X_2 = 0

cancelled once X_2 is integrated out!

can be tuned to zero

This fits the picture of an interpolating wall between two theories of different dimensions!

Conclusions and Outlook

- ➔ **Tachyon condensation in bosonic string theory leads to bubbles of nothing and dimension changing bubbles.**
  One can be explorative and attempt to capture the relevant physics with an effective action. This allows us to describe it as an example of a dynamical cobordism.
- ➔ **Similar transitions take place in superstring theories, and even between different string theories.**

  Hellerman, Swanson 0705.0980
- ➔ **Very stringy realization of cobordisms, might teach us about cobordisms to nothing from the worldsheet perspective.**

Closed string tachyon condensation as an inherent instability of the theory

Thanks for listening!

Closed string tachyon condensation as a stringy cobordism to nothing