New solutions for any open string background

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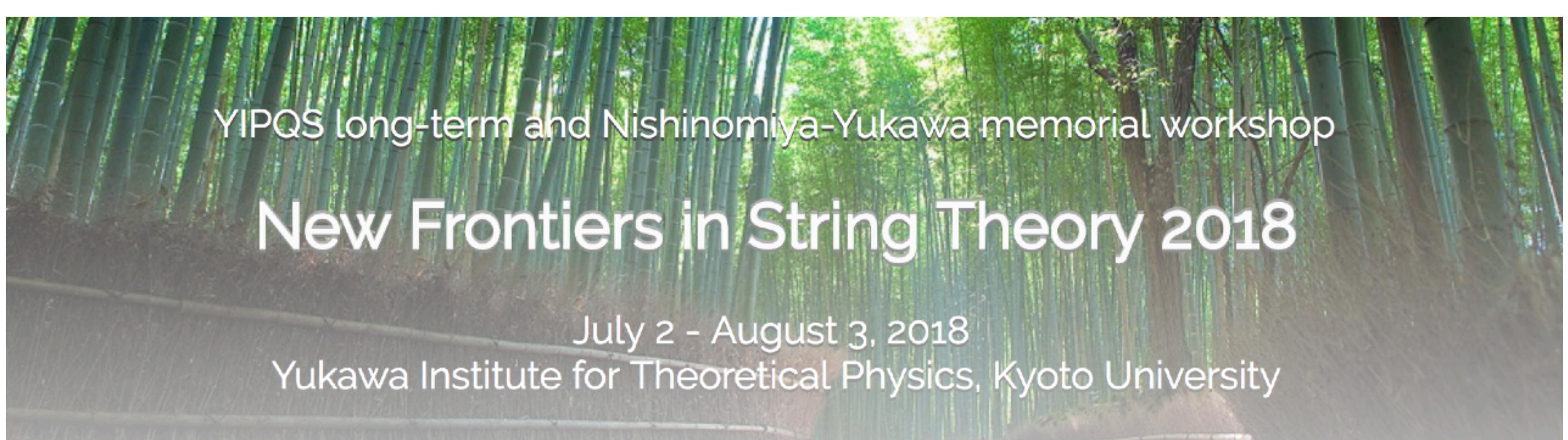
to appear, with Ted Erler



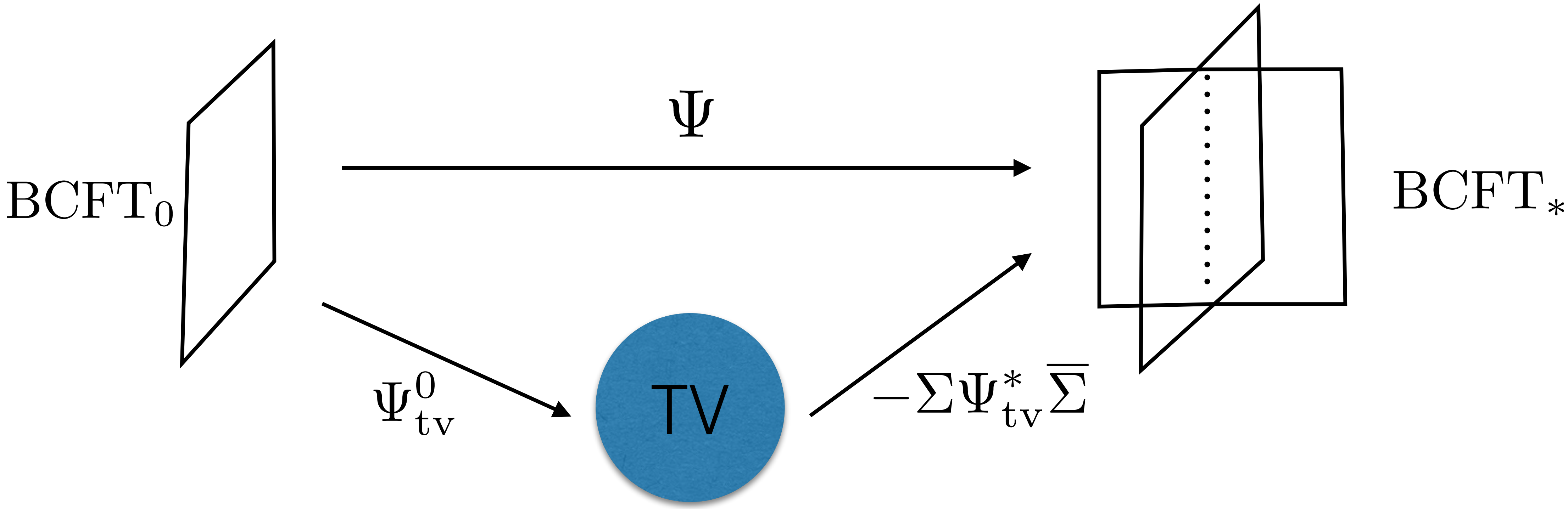
OSFT CONJECTURE

Given OSFT defined on a given D-brane system

- Classical solutions describing any other D-brane system
- Background independence by expanding around the solution plus field redefinition

- EM solution (Erler, CM 2014)

$$\Psi = \Psi_{\rm tv}^0 - \Sigma\,\Psi_{\rm tv}^*\,\overline{\Sigma}$$



- Equation of motion

$$Q_{\rm tv}\Sigma = Q\Sigma + \Psi_{\rm tv}^0\Sigma - \Sigma\Psi_{\rm tv}^* = 0$$

$$Q_{\rm tv}\overline{\Sigma} = Q\overline{\Sigma} + \Psi_{\rm tv}^*\overline{\Sigma} - \overline{\Sigma}\Psi_{\rm tv}^0 = 0$$

$$\overline{\Sigma}\Sigma = 1$$

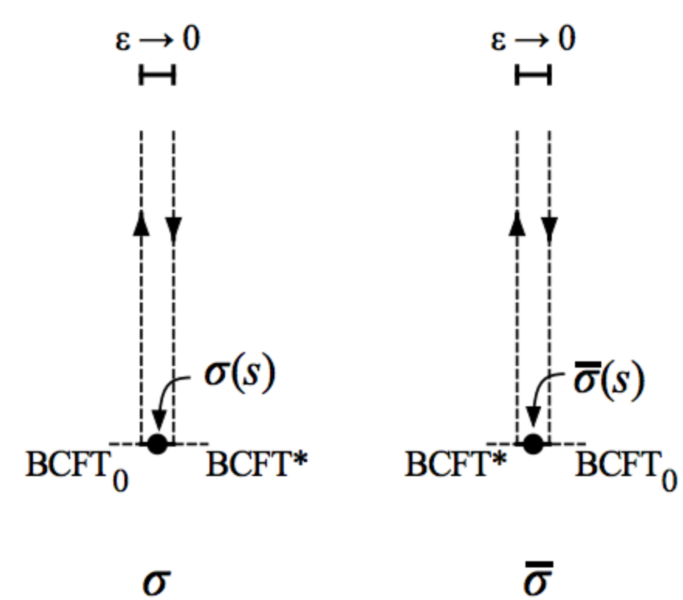
- In 2014 we realised this structure as

$$\Sigma = Q_{\text{tv}}\left(\frac{1}{\sqrt{1+K}}B\sigma\frac{1}{\sqrt{1+K}}\right)$$

$$\overline{\Sigma} = Q_{\text{tv}}\left(\frac{1}{\sqrt{1+K}}B\overline{\sigma}\frac{1}{\sqrt{1+K}}\right)$$

using identity-like insertions of weight zero matter bcc operators

$$\sigma = U_1^*\,\sigma(0)\,|\,0\rangle$$
$$\overline{\sigma} = U_1^*\,\overline{\sigma}(0)\,|\,0\rangle$$



- Fundamental property to satisfy eom

$$\bar{\sigma}\sigma = 1$$

achieved thanks to "time trick" (no collision, weight=0)

$$\sigma = e^{i\sqrt{h}X^0}\sigma_*^{(c=25)}$$

$$\bar{\sigma} = e^{-i\sqrt{h}X^0}\bar{\sigma}_*^{(c=25)}$$

- Only static background (lumps, multiple branes, but no time dependence)

- Broken Lorentz invariance by "pure gauge" excitations in time CFT

- **Potential associativity anomalies (real problem for superstring!)**

$$\sigma\bar{\sigma} = \frac{g_*}{g_0} = \frac{\langle 1\rangle^{\mathrm{BCFT}_*}}{\langle 1\rangle^{\mathrm{BCFT}_0}} \qquad \rightarrow \qquad (\sigma\bar{\sigma})\sigma \neq \sigma(\bar{\sigma}\sigma)$$

- Therefore we search for a new realisation of the EM basic ingredients
- First note that we can write

$$\Sigma = Q_{\text{tv}}(A\tau) \qquad Q_{\text{tv}}\, A = 1$$

$$\overline{\Sigma} = Q_{\text{tv}}(\bar{\tau}A) \qquad A^2 = 0$$

$$\overline{\Sigma}\Sigma = Q_{\text{tv}}(\bar{\tau}A)\, Q_{\text{tv}}(A\tau) = Q_{\text{tv}}(\bar{\tau}A Q_{\text{tv}}(A\tau)) = Q_{\text{tv}}(\bar{\tau}A\tau) = 1$$

Provided $\boxed{\bar{\tau}A\tau = A}$

- Simplest (but too singular) realization

$$\Psi_{\text{tv}} = \sqrt{1-K}\, c\, \sqrt{1-K} \qquad A = B \qquad \boxed{\bar{\sigma} B \sigma = B}$$

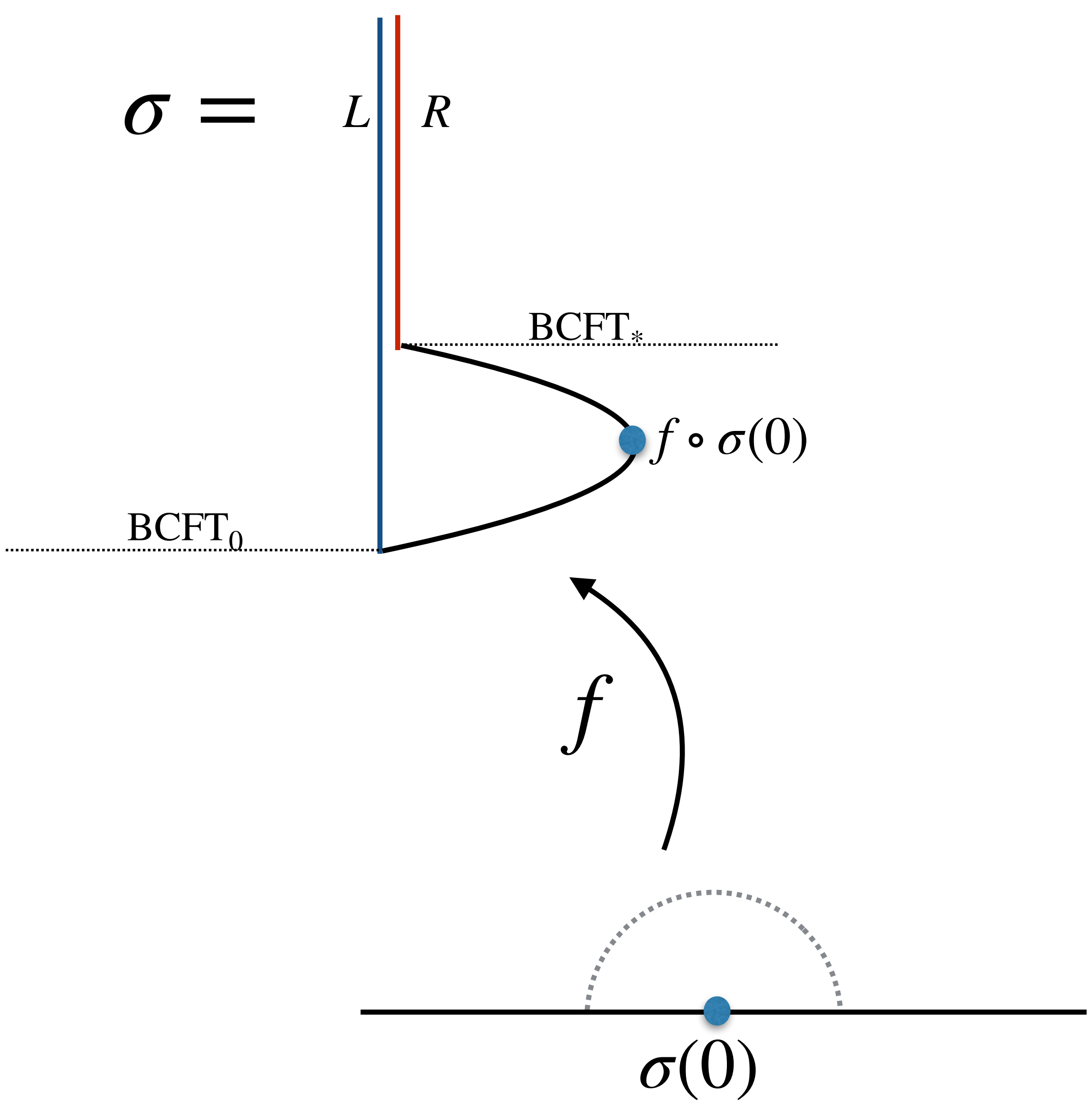
- More generally

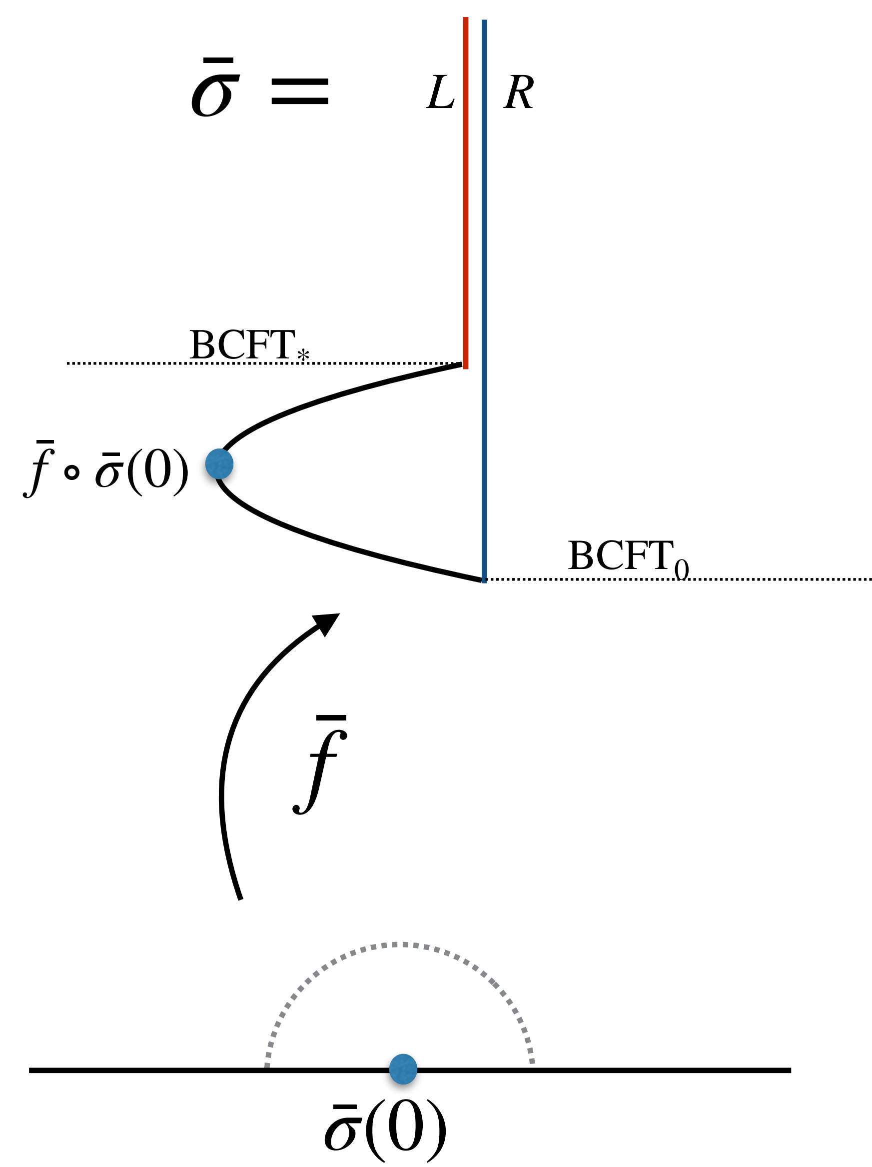
$$\Psi_{\text{tv}} = \sqrt{F} c \frac{KB}{1-F} c \sqrt{F} \qquad A = B \frac{1-F}{K} \qquad \bar{\tau} = \sqrt{\frac{1-F}{K}} \bar{\sigma} \sqrt{\frac{K}{1-F}} \qquad \tau = \sqrt{\frac{K}{1-F}} \sigma \sqrt{\frac{1-F}{K}}$$

$$\bar{\tau} A \tau = A$$

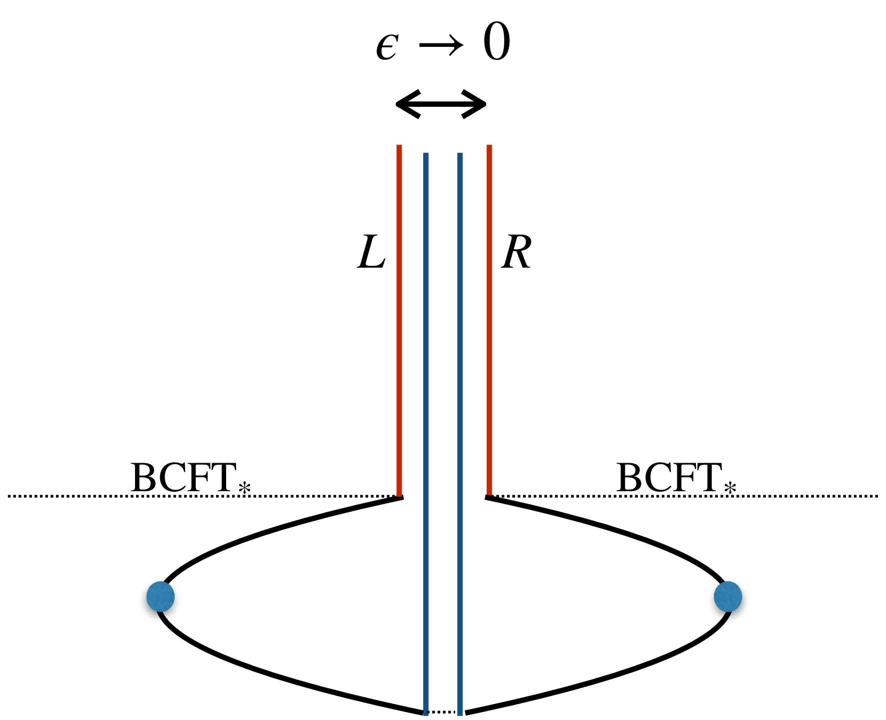
- So we are after $\bar{\sigma} B \sigma = B$
- Can $(\sigma, \bar{\sigma})$ be something else than identity-like?

The idea of the Flags





- Multiplying in the order $\bar{\sigma} \star \sigma$: degenerating surface



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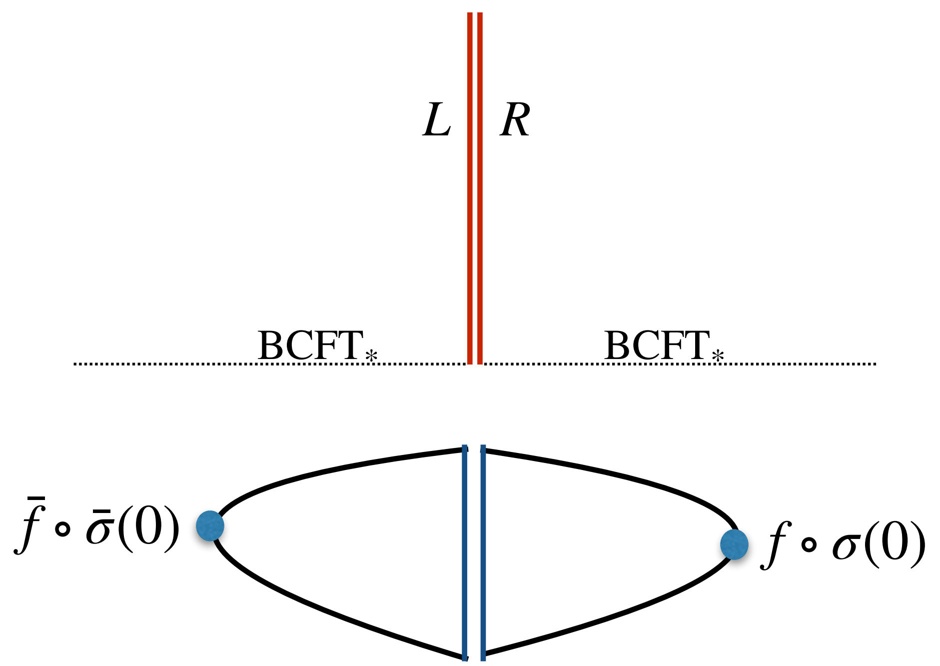
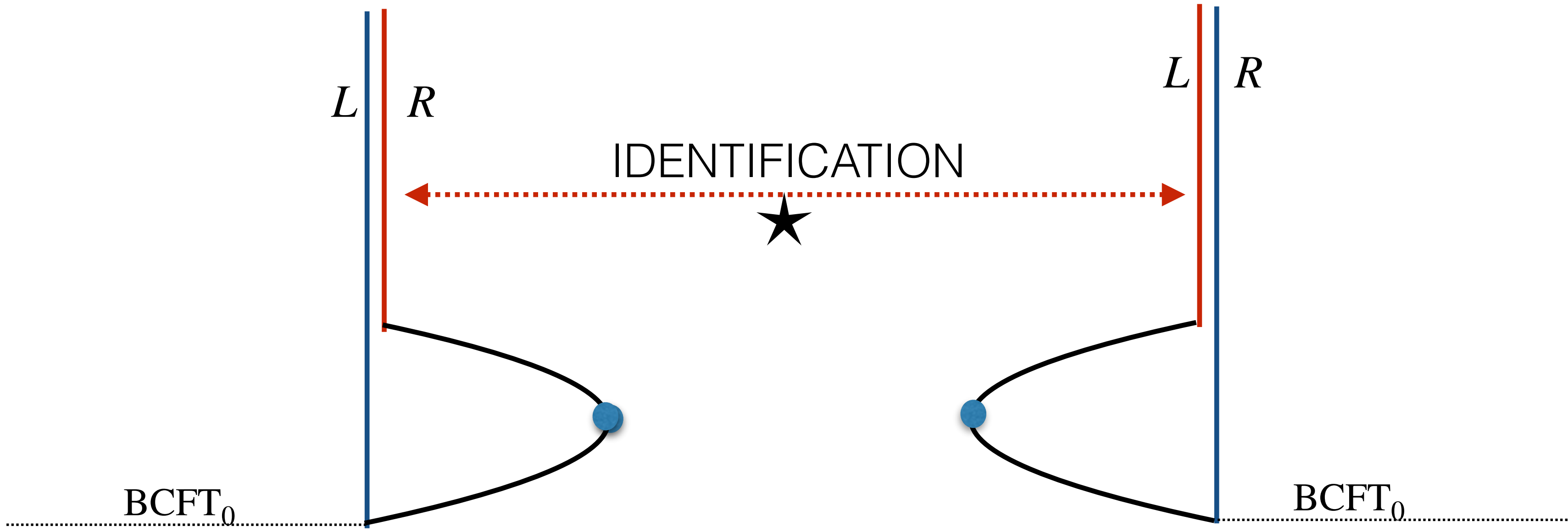


$$= \frac{1}{g_*} \langle I \circ \bar{\sigma}(0)\, \sigma(0) \rangle \times 1^{(*)}$$

(normalization)

$$\bar{\sigma}\sigma = 1$$

- Multiplying in the order $\sigma \star \bar{\sigma}$: ***new kind of surface state***



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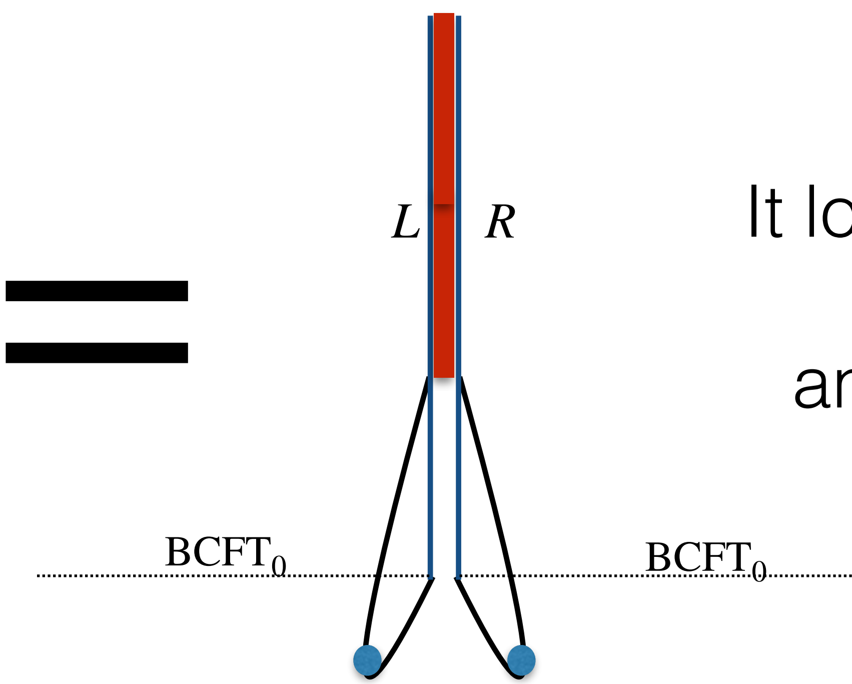


It looks like the identity string field towards the midpoint
but it has a non degenerate boundary
and it is “left/right” factorized towards the endpoints!

$$\sigma\bar{\sigma} = \text{projector}$$

- Therefore we have a “new kind” of Partial Isometry

$$\bar{\sigma}\sigma = 1$$

$$\sigma\bar{\sigma} = P$$

- Now associativity is OK (no multiple collisions)

$$\bar{\sigma}\,\sigma\,\bar{\sigma} = \bar{\sigma}$$

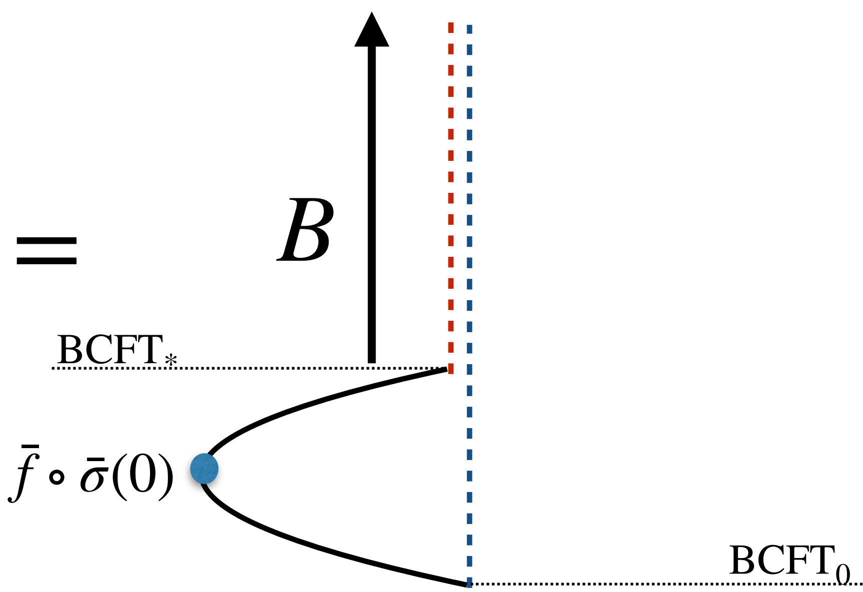
$$\sigma\,\bar{\sigma}\,\sigma = \sigma$$

- But to have a solution we need $\bar{\sigma}\, B\, \sigma = B$

$$B = \int \frac{dz}{2\pi}\, b(z)$$

$$\bar{\sigma}\, B\, \sigma = B\bar{\sigma}\sigma - [B, \bar{\sigma}]\, \sigma = B - \bar{\sigma}_b\, \sigma$$

$$\bar{\sigma}_b \equiv [B, \bar{\sigma}] =$$



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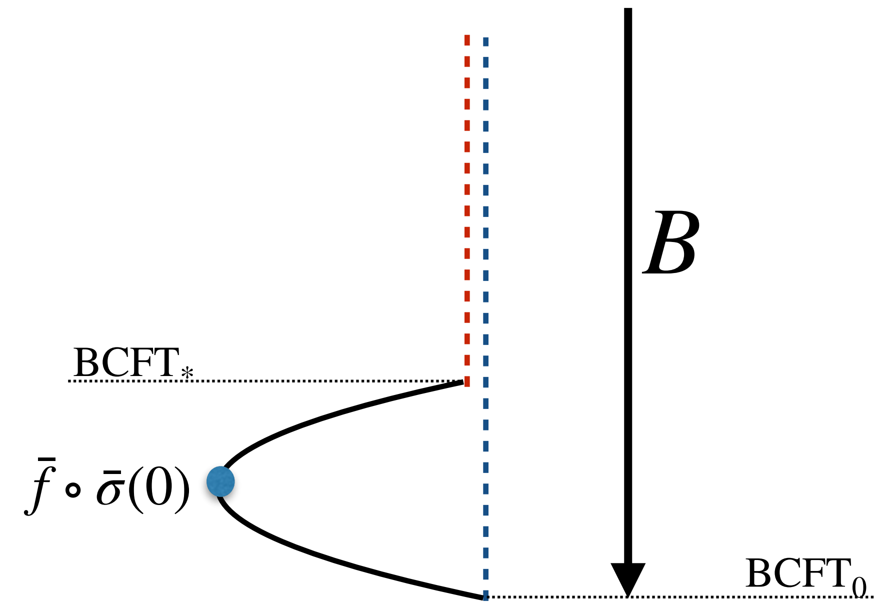

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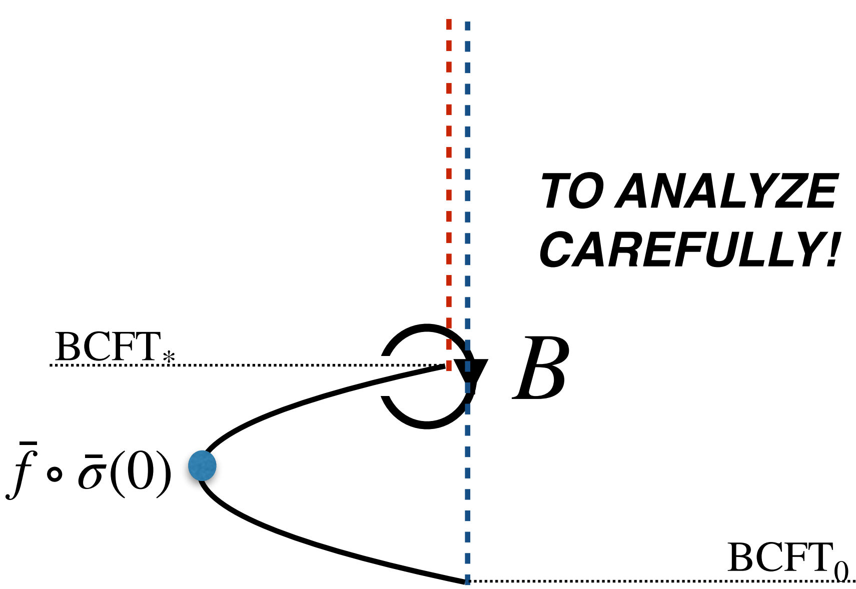


But (see later) we have proven that

$$\lim_{\epsilon \to 0} \bar{\sigma}_b\, \Omega^{\epsilon}\, \sigma = 0$$

$$\boxed{\bar{\sigma}\, B\, \sigma = B}$$

- So we have a solution of the EM form (correct energy and boundary state)

$$\Psi = \Psi_{\rm tv}^{0} - \Sigma\, \Psi_{\rm tv}^{*}\, \overline{\Sigma}$$

$$Q_{\Psi,0}\Sigma = Q_{\rm tv}\Sigma = 0 \qquad\qquad Q_{0,\Psi}\overline{\Sigma} = Q_{\rm tv}\overline{\Sigma} = 0$$

$$Q_{\Psi}\,(\Sigma\overline{\Sigma}) = Q_{\rm tv}\,(\Sigma\overline{\Sigma}) = 0$$

- Fluctuations and background independence

$$S^{(0)}(\Psi + \Sigma\phi\bar{\Sigma}) = \frac{1}{2\pi^2}(g_0 - g_*) + S^{(*)}(\phi)$$

- Field redefinition (see also Kishimoto, Masuda, Takahashi)

$$\psi = \Sigma\phi\overline{\Sigma}, \quad (\,\ldots\,)$$

MULTIBRANES

- Easily realized by orthogonal flags

$$\bar{\Sigma}_i \Sigma_j = \delta_{ij}$$

- Obtained by diagonalizing the matrix of inner products

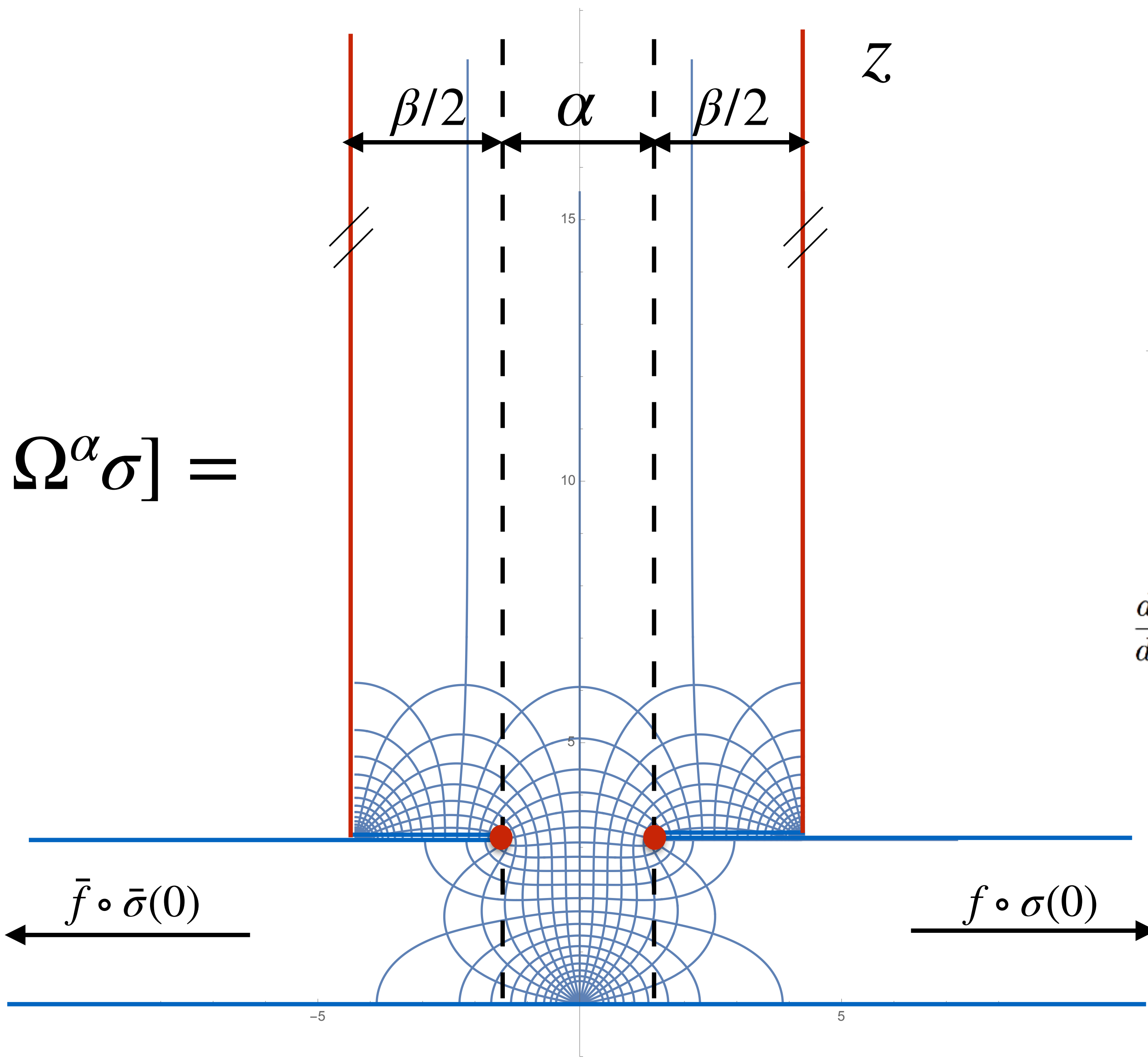
$$\delta_{ij} = \langle I \circ \bar{\sigma}_i(0) \sigma_j(0) \rangle$$

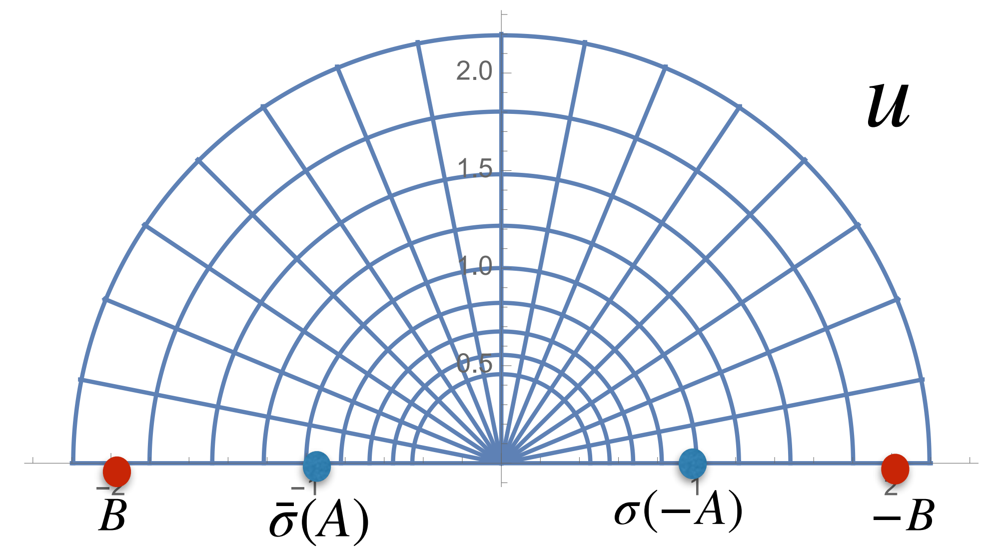
- Universal multibranes: take (σ_i, σ_j) in the matter Verma module of the identity and diagonalize the Gram matrix.

EXPLICIT REALIZATION OF THE FLAGS

- Take the flags to be horizontal semi-infinite strips
  (needed for having “simple” Schwartz-Christoffel map)

$$\mathrm{Tr}[\Omega^{\beta}\,\bar{\sigma}\,\Omega^{\alpha}\sigma] =$$





$$z = F(u) = \frac{2\ell}{\pi}\left[\frac{A(1+B^2)}{B^2-A^2}\tan^{-1}u + \tanh^{-1}\frac{u}{A}\right]$$

$$\frac{dz}{du} = F'(u) = \frac{2\ell A}{\pi}\,\frac{1+A^2}{B^2-A^2}\,\frac{u^2-B^2}{u^2-A^2}$$

$$\alpha = \frac{4\ell}{\pi}\left[\frac{A(1+B^2)}{B^2-A^2}\tan^{-1}B + \tanh^{-1}\frac{A}{B}\right]$$

$$\alpha+\beta = \frac{2\ell A(1+B^2)}{B^2-A^2}$$

Basic properties of the "strip" flags

$$\lim_{\epsilon\to 0} \bar{\sigma}\,\Omega^{\epsilon}\,\sigma = 1$$

$$\lim_{\epsilon\to 0} \bar{\sigma}\,B\Omega^{\epsilon}\,\sigma = B$$

This is all very good, but one has to be careful with the c ghost

$$\lim_{\epsilon\to 0} c\Omega^{\epsilon}\bar{\sigma} = 0$$

$$\lim_{\epsilon\to 0} \sigma\Omega^{\epsilon}c = 0$$

These anomalies can be consistently avoided by uplifting the c ghost in the bulk

$$c_{i\epsilon}\,\bar{\sigma}\sigma = \bar{\sigma}\sigma\,c_{i\epsilon} = c_{i\epsilon}, \qquad c_{i\epsilon} \equiv e^{i\epsilon K}ce^{-i\epsilon K}, \quad \forall\epsilon > 0$$

FOCK SPACE COEFFICIENTS

- The solution is concretely defined if we can expand it in Fock space

$$\Psi = \sum_i \psi_i \, c\phi^i(0)\,|\,0\rangle \, + \, (\,\dots)$$

- From the very structure of the solution we will have that

$$\psi_i = K(h_i, h_\sigma)\, C_{i\sigma\bar{\sigma}}$$

- ***K*** is a universal function which depends on the choice of tachyon vacuum and on the details of the Schwarz-Christoffel map (quite complicated)

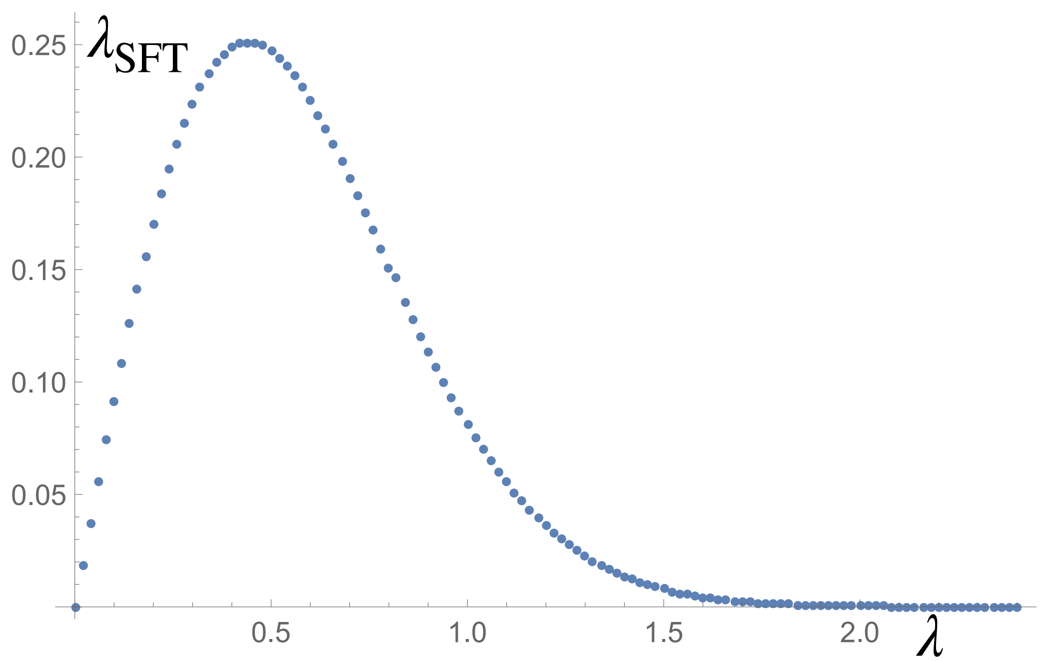
- We started analysing the following ghost number zero toy model

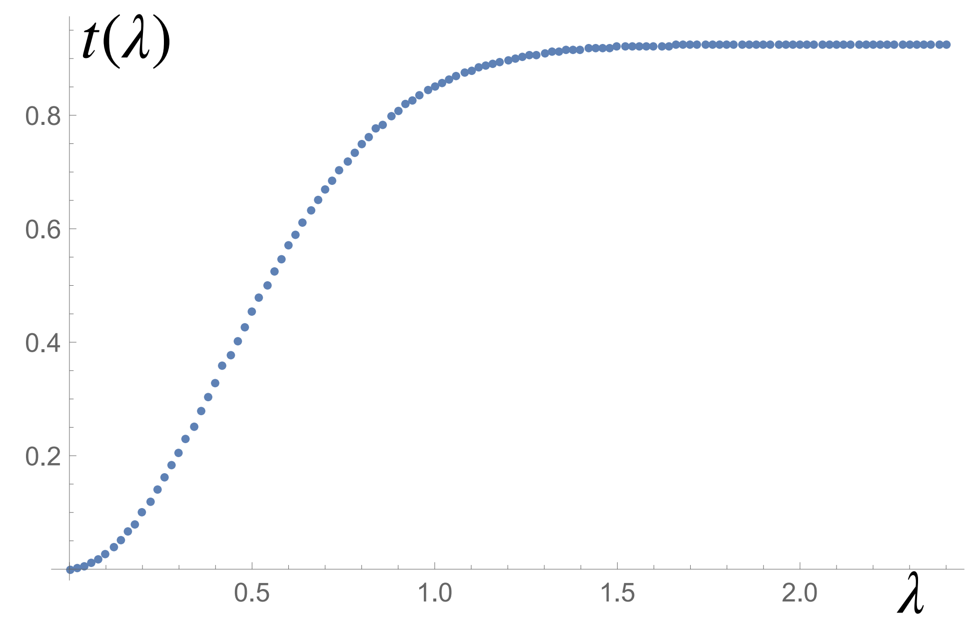
$$\Psi_{\rm toy} = \frac{1}{\sqrt{1+K}}\sigma_1\frac{1}{1+K}\bar{\sigma}_1\frac{1}{\sqrt{1+K}} - \frac{1}{\sqrt{1+K}}\sigma_*\frac{1}{1+K}\bar{\sigma}_*\frac{1}{\sqrt{1+K}}$$

TOY MODEL MARGINAL DEFORMATIONS

- Coefficients of the marginal field and the tachyon

$$\Psi^{(\mathrm{marg})}_{\mathrm{toy}}(\lambda) = t(\lambda)\,|0\rangle + \lambda_{\mathrm{SFT}}(\lambda)\, j_1\,|0\rangle + (\ldots)$$





- Same qualitative behaviour as in (Schnabl-CM'15) for the solution (CM)

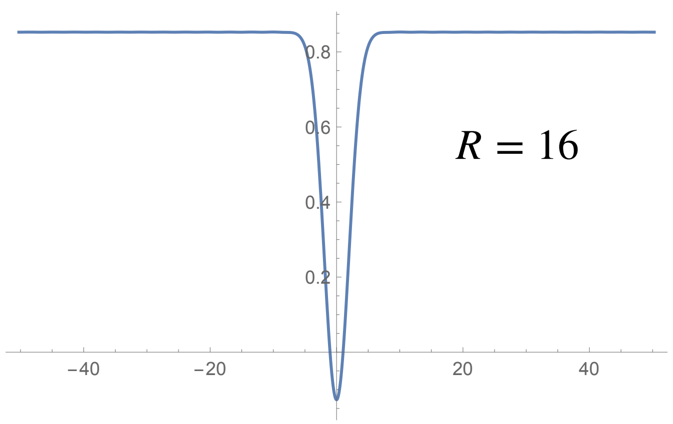
$$\Psi = \frac{1}{1+K}Q\sigma\frac{1}{1+K}\overline{\sigma} + Q(\ldots)$$

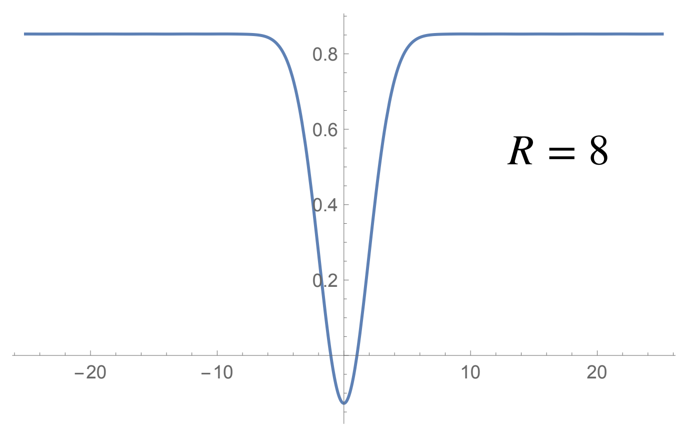
- This behaviour seems generic

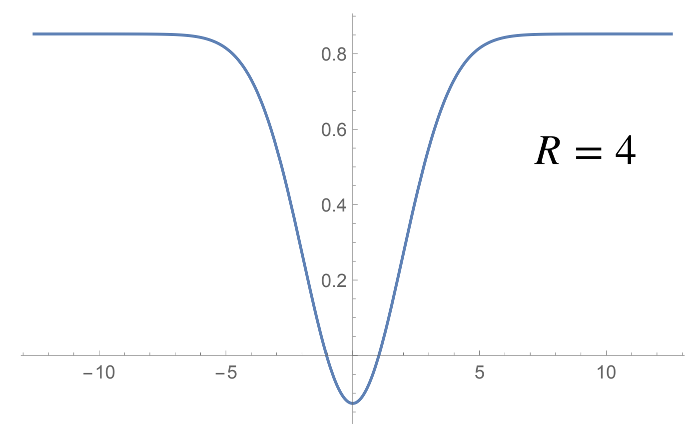
TOY MODEL LUMPS

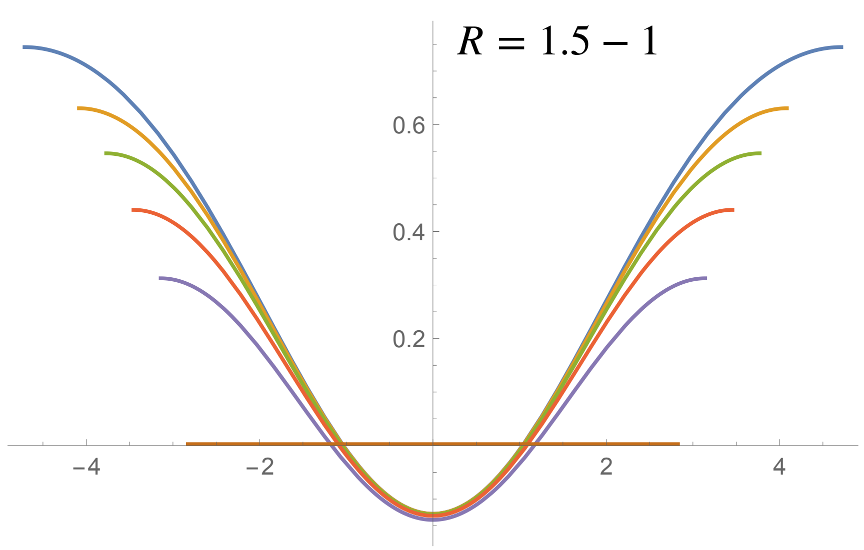
- Choose the bcc to be the well known ND twist fields (h=1/16) at radius R

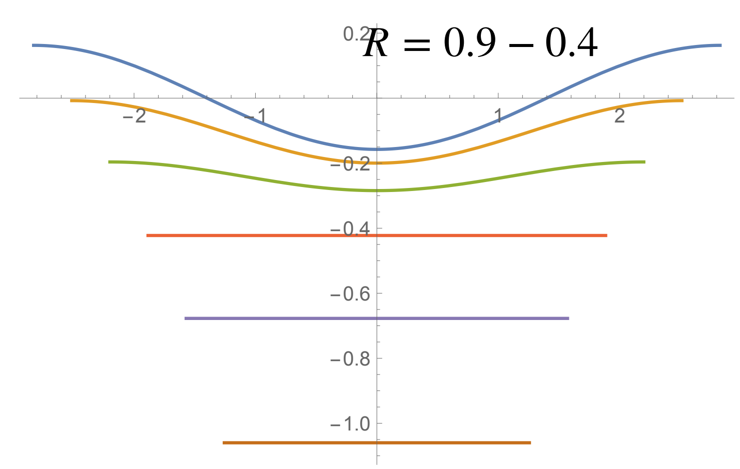
$$\Psi^{(\mathrm{lump})}_{\mathrm{toy}} = \sum_n t_n \, e^{i\frac{n}{R}X}(0)\,|0\rangle + (\ldots) \qquad\qquad t(x) = t_0 + 2\sum_{n>0} t_n \cos\frac{n}{R}x$$











(POSITIVE ENERGY)

Same qualitative behaviour as in Siegel gauge and previous EM.

Zero momentum coefficient not always negative for positive energy solutions

FINAL COMMENTS

- Our previous construction is now realized in a fully associative way.
- The old realization can be obtained in a limit where flags degenerate (changing the flags is a gauge transformation)
- Solutions can be consistently composed using multi-flags.
- Partial isometries play a structural role (cfr GMS, Schnabl,… 2000): solution generating technique from the tachyon vacuum.
- This is the first concrete analytic solution outside the wedge (or related) algebra (generalizations?)
- Do we necessarily have to pass through the TV?
- More general (and mysterious) solutions are available (see Ted’s talk at SFT@HRI Feb 2018)
- ***This is a better starting point for generalization to the superstring (ULTIMATE GOAL)***

THANK YOU!

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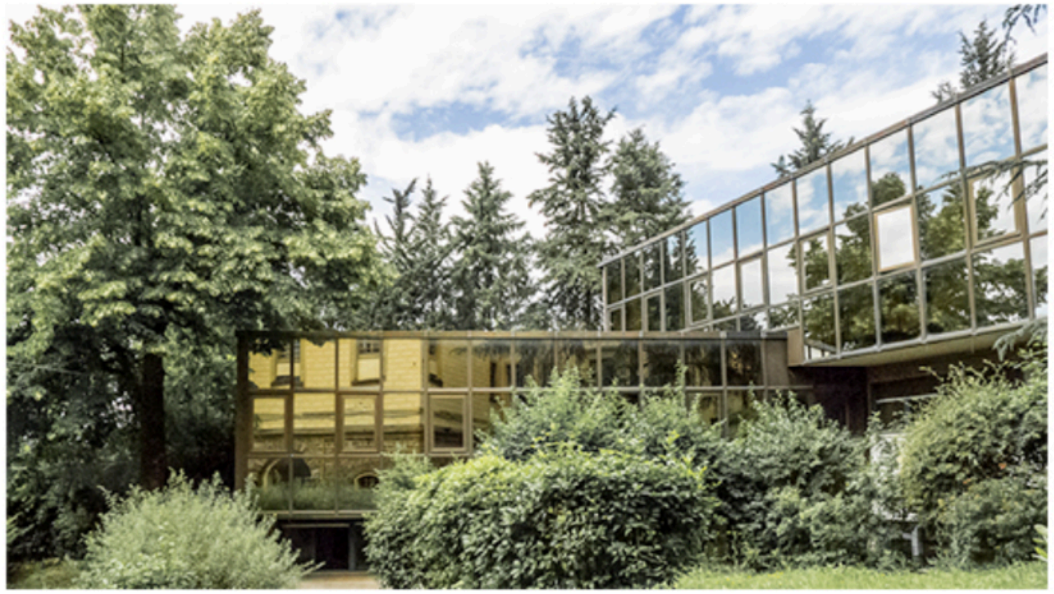

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