TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

One-loop Adjoint Masses for Non-Supersymmetric Intersecting Branes

Pascal Anastasopoulos

Based on: 1105.0591 [hep-th]
with I. Antoniadis, K. Benakli, M. Goodsell, A. Vichi

Corfu - 12/09/2011

Plan of the talk

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- Motivation

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- D-Brane Setup

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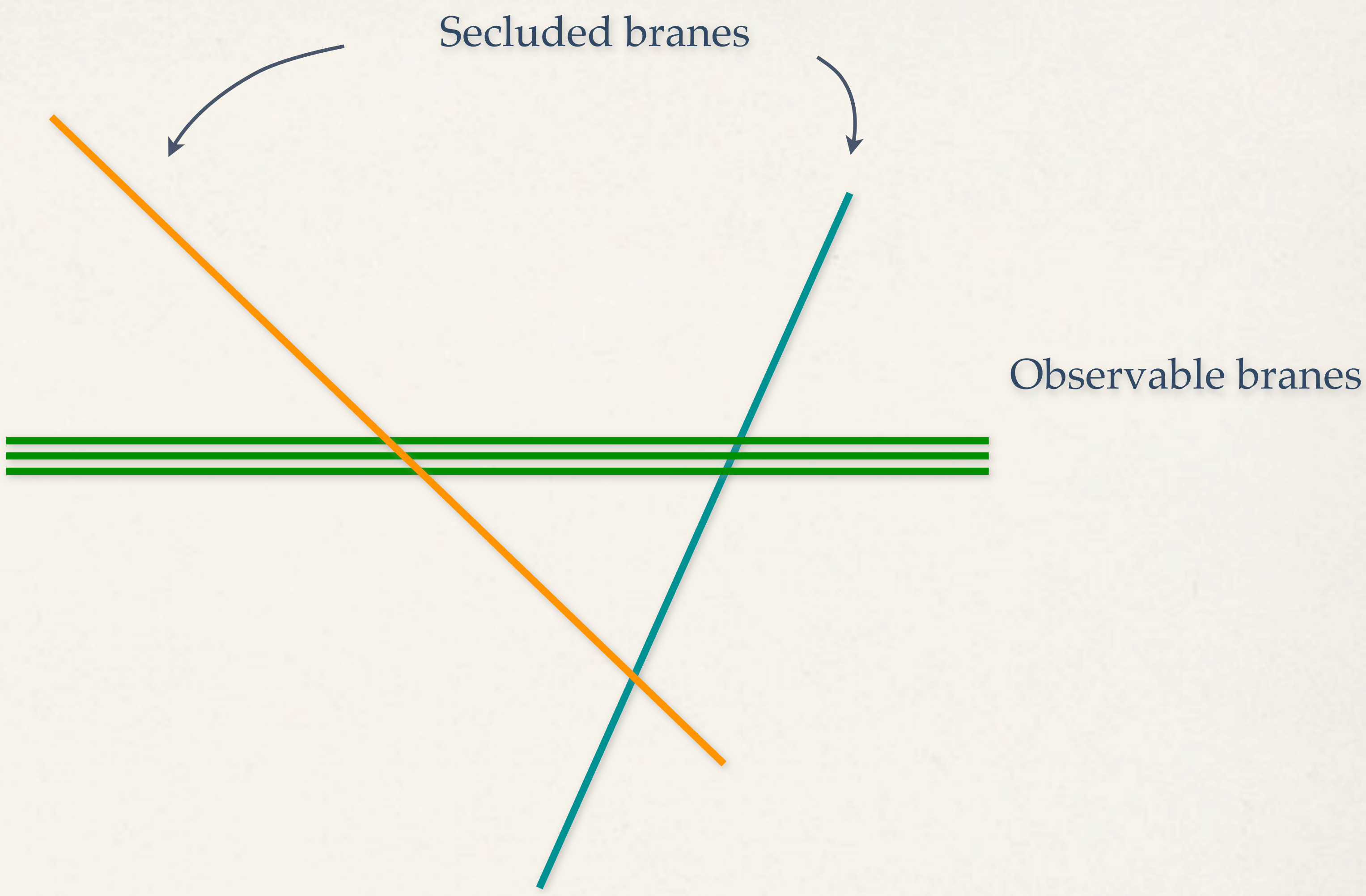
- Conclusions



Introduction and motivation

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- A supersymmetric vacuum can be obtained through a specific choice of intersection angles between D-branes.

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- However, some adjoint scalars become tachyonic in the effective field theory.

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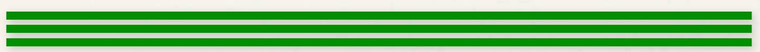

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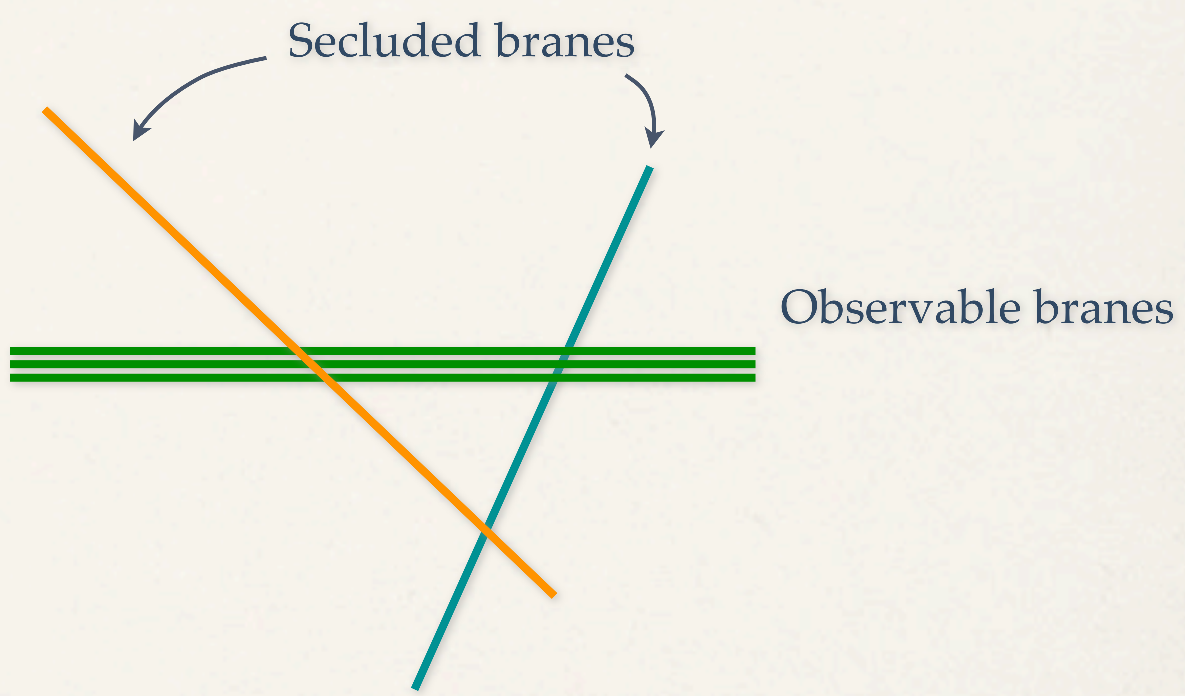

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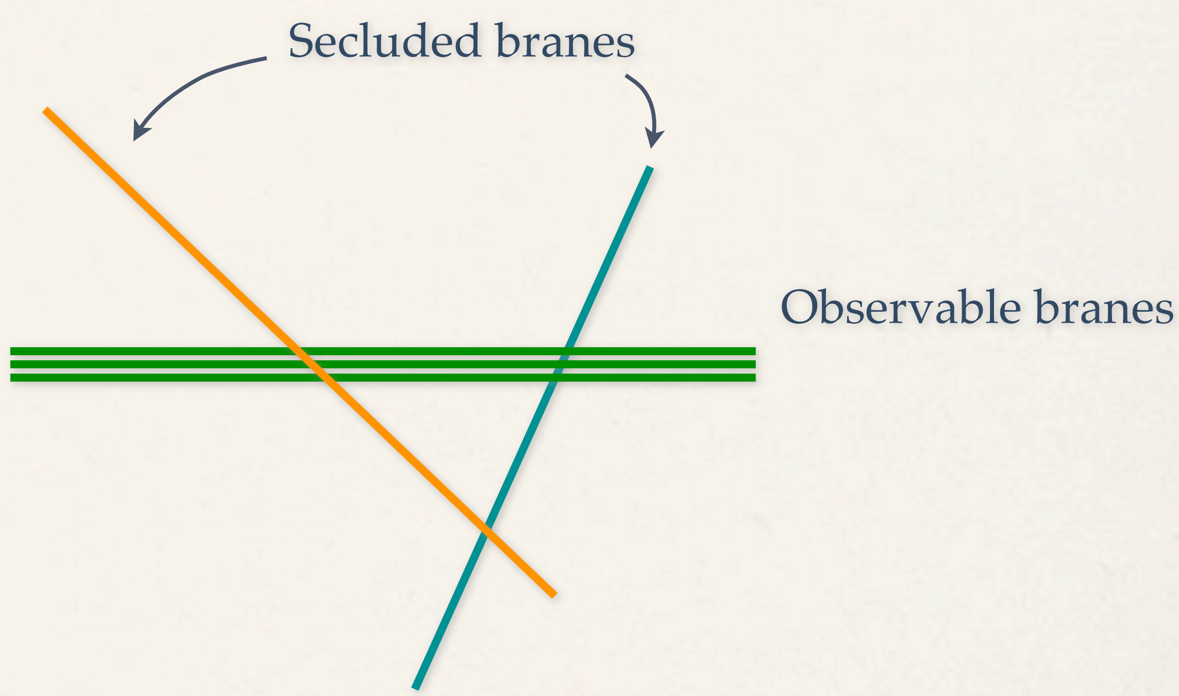

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  - Secluded branes: that intersect with the observable sector.
- Supersymmetry breaking will be communicated to OS via messengers aka strings at the intersections.

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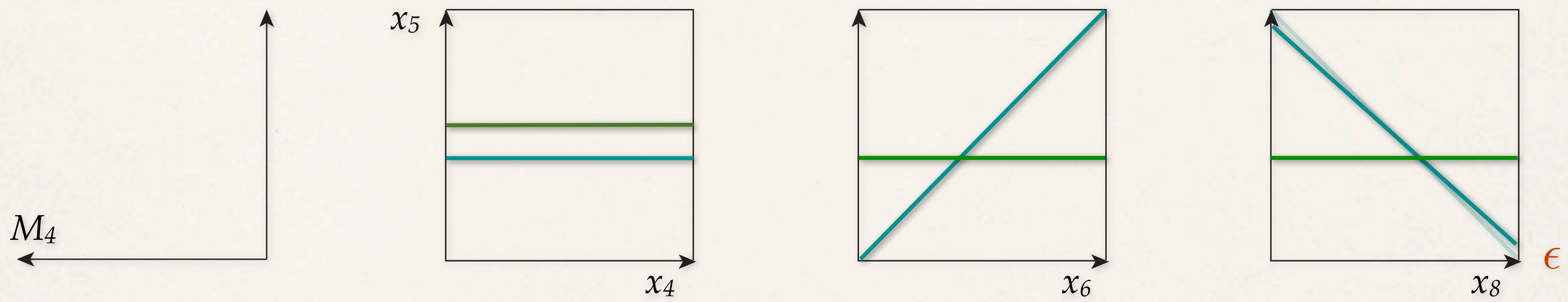
- The mass corrections vanish for an $\mathcal{N} \approx 1$ sector. This is due to the absence of couplings between the messengers and scalars in adjoint representations at the one-loop level.
- For the $\mathcal{N} \approx 2$ and $\mathcal{N} \approx 4$ cases, one can derive the one-loop effective potential and read from there the masses of the adjoint representations.



D-brane setup

Brane configuration

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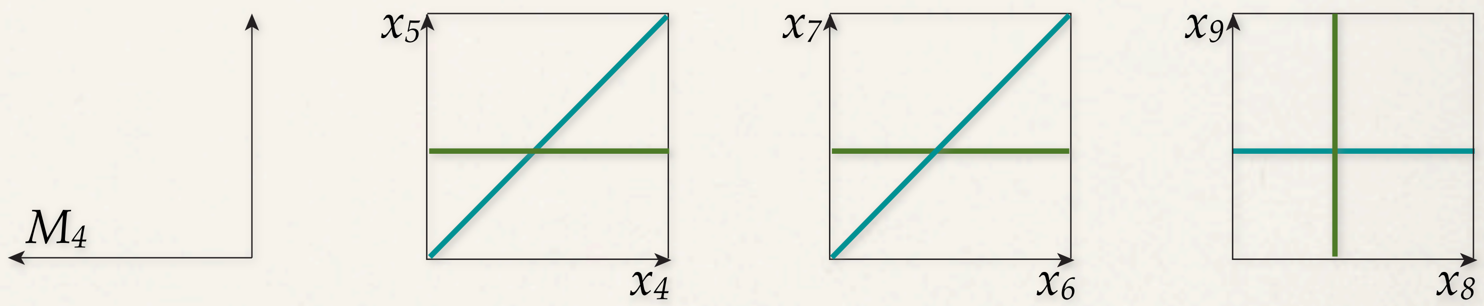

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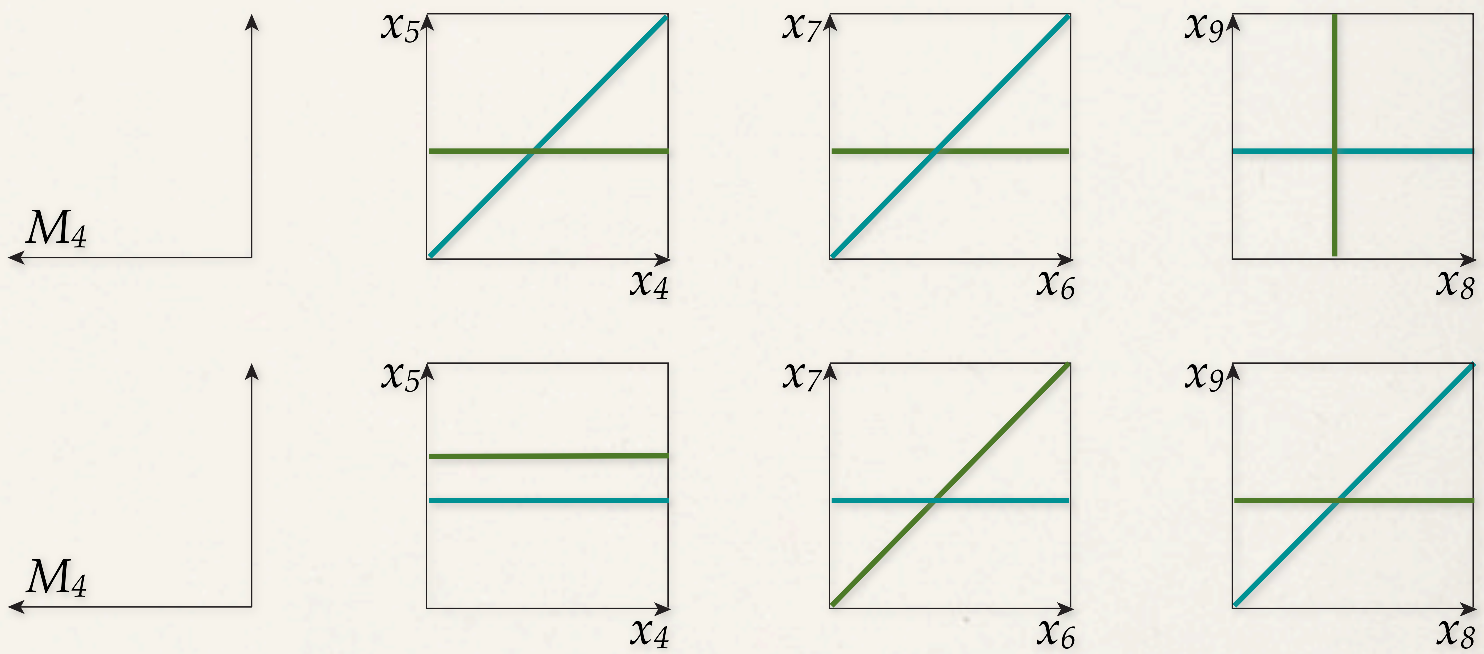

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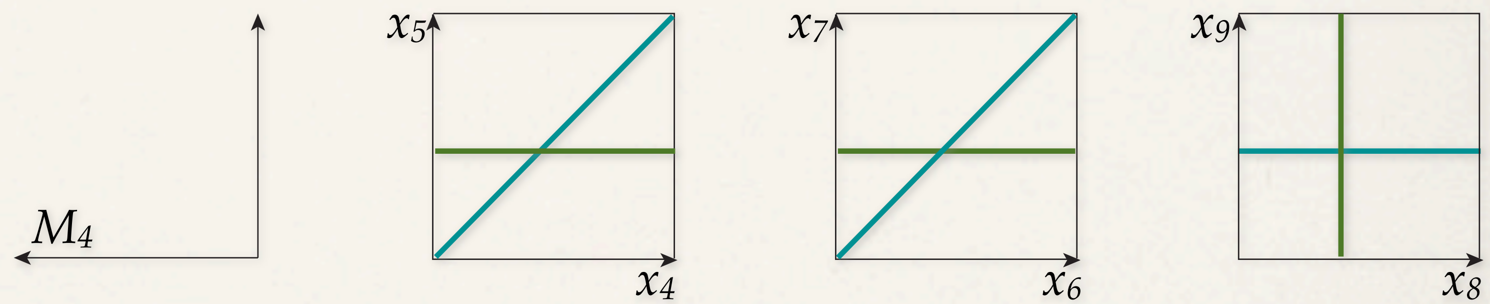

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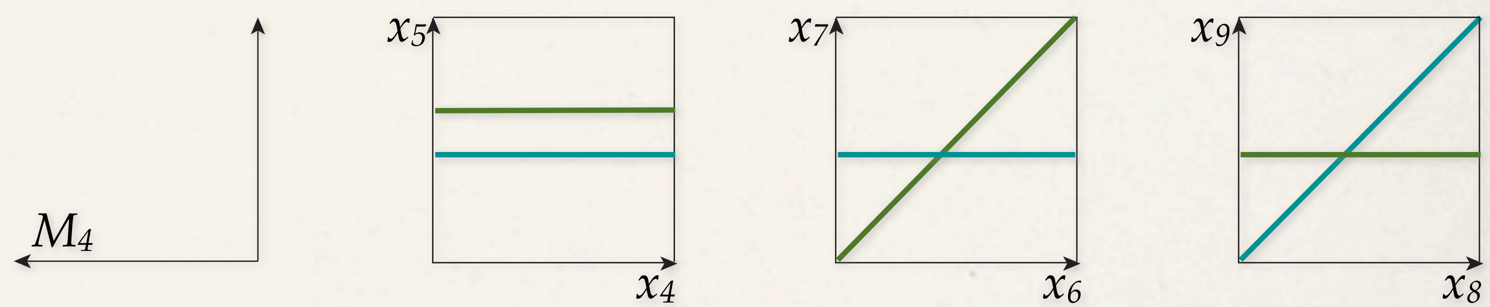
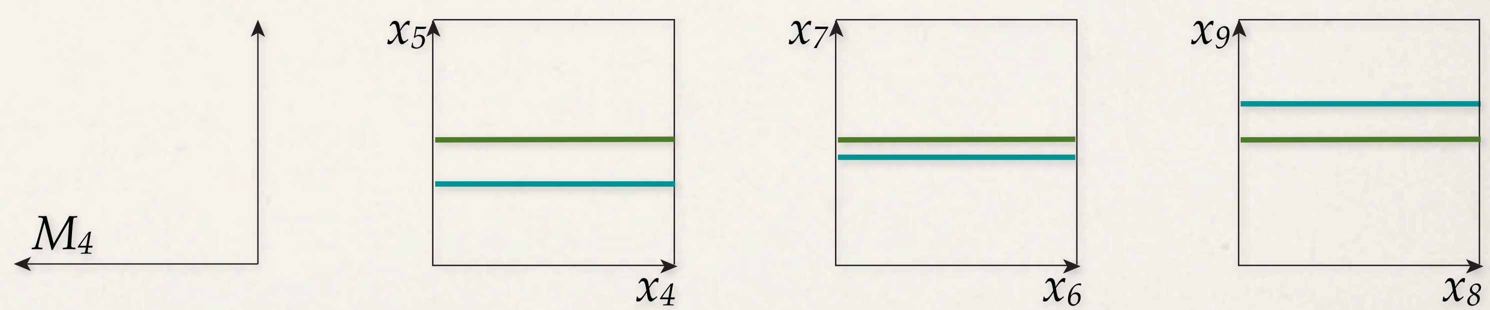


  - $\mathcal{N} = 4$.



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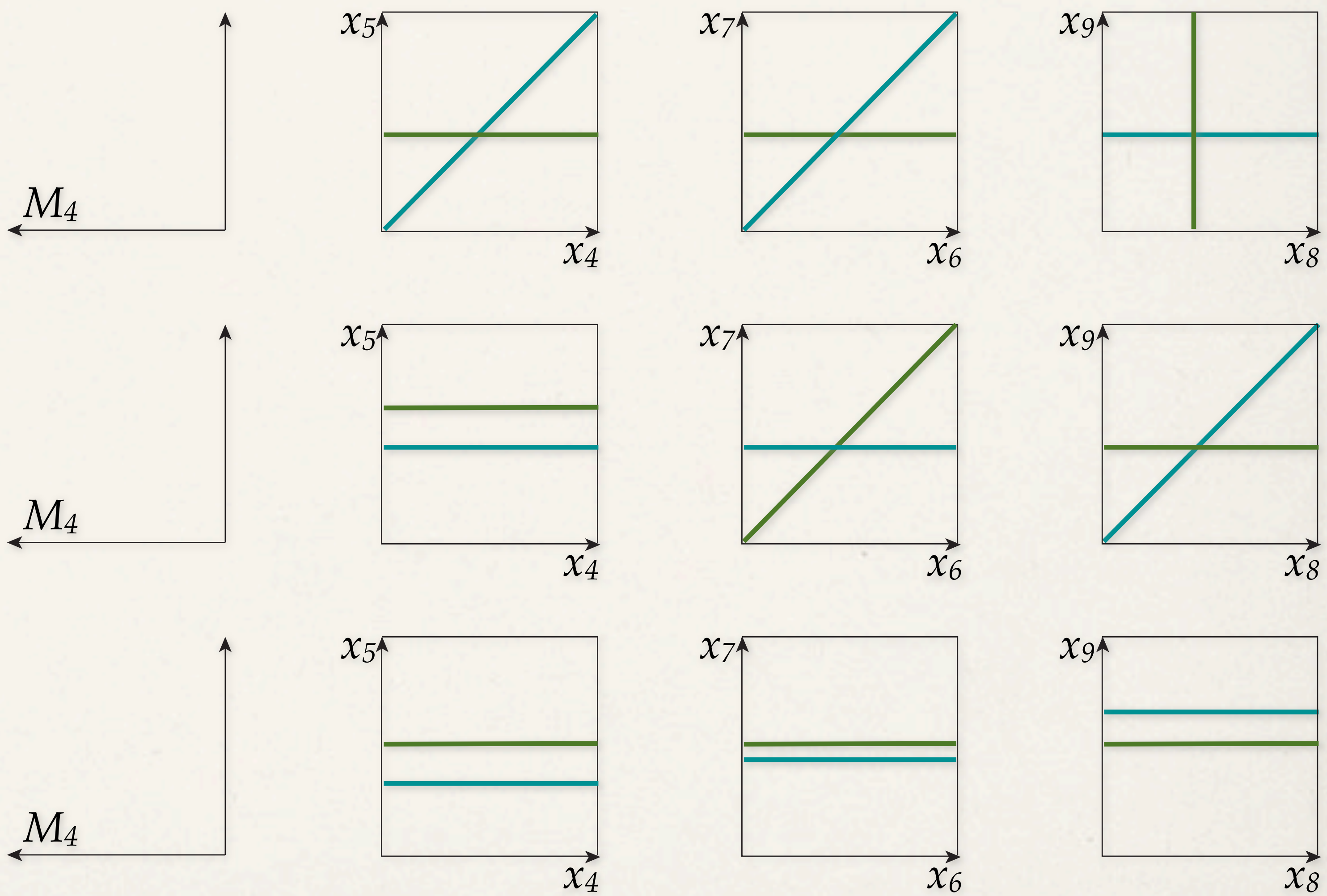

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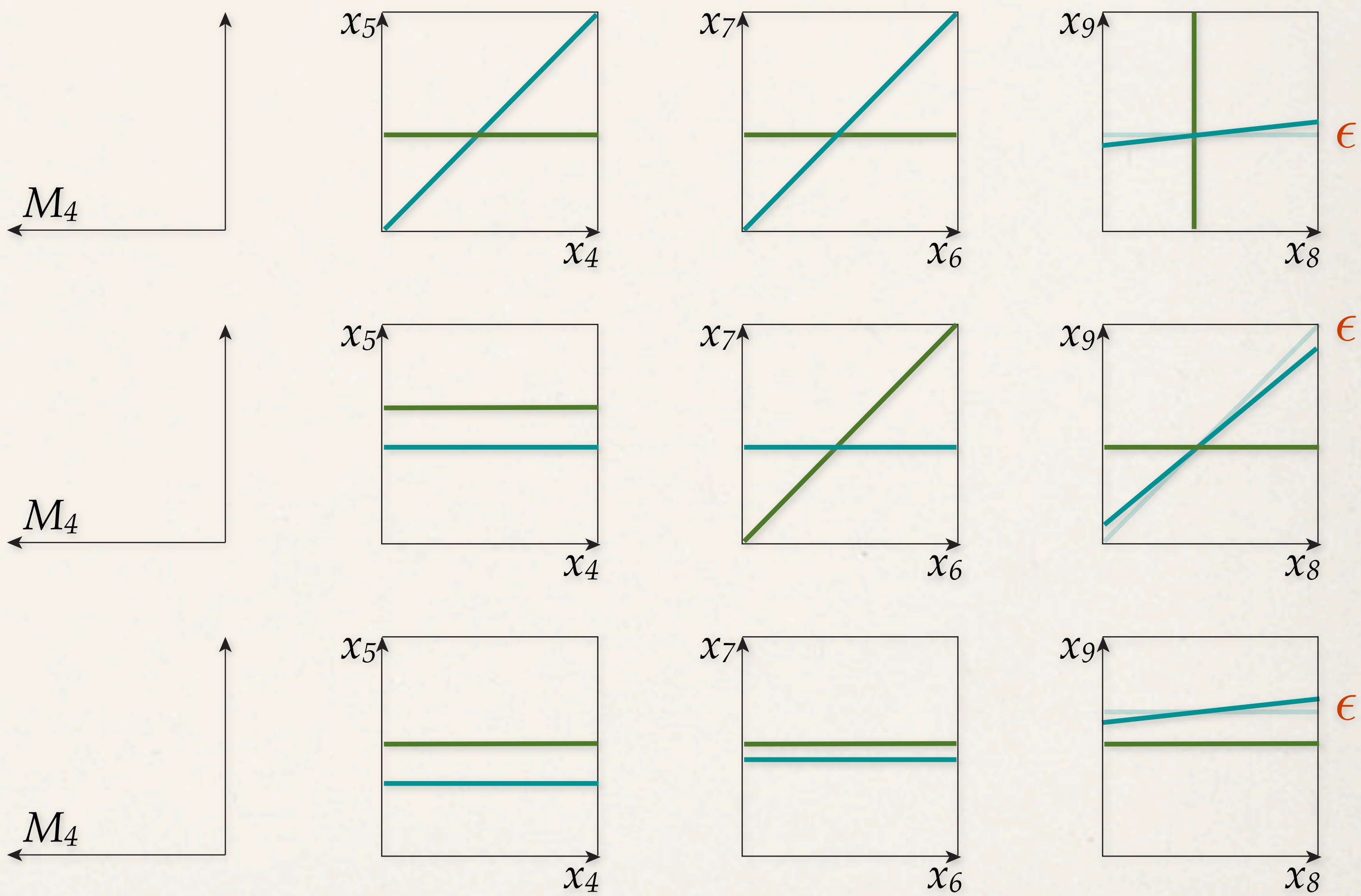

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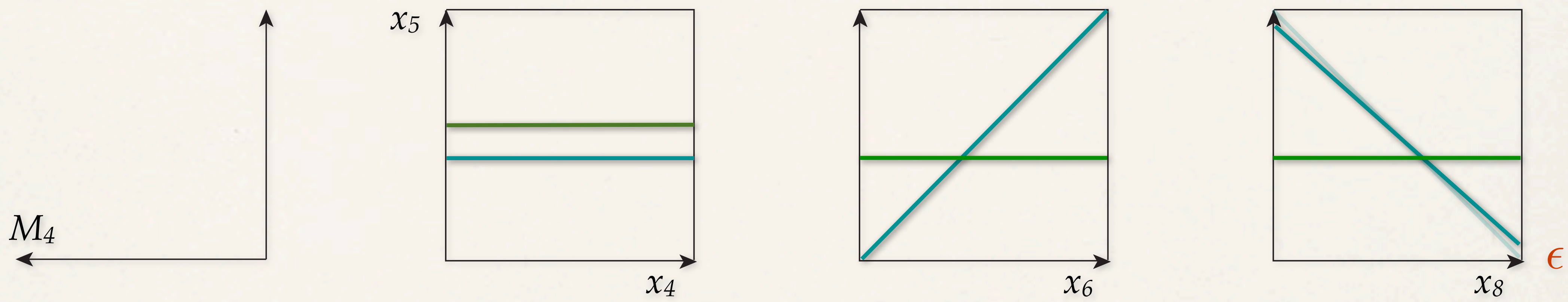

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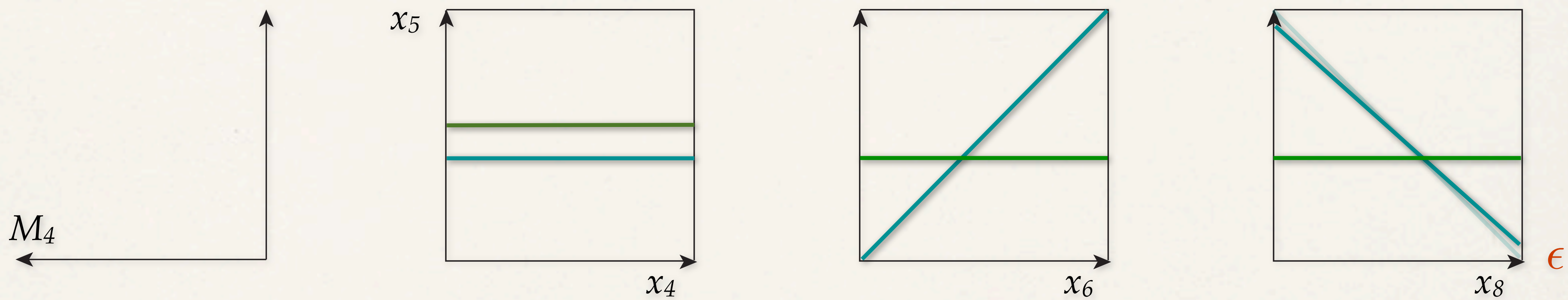

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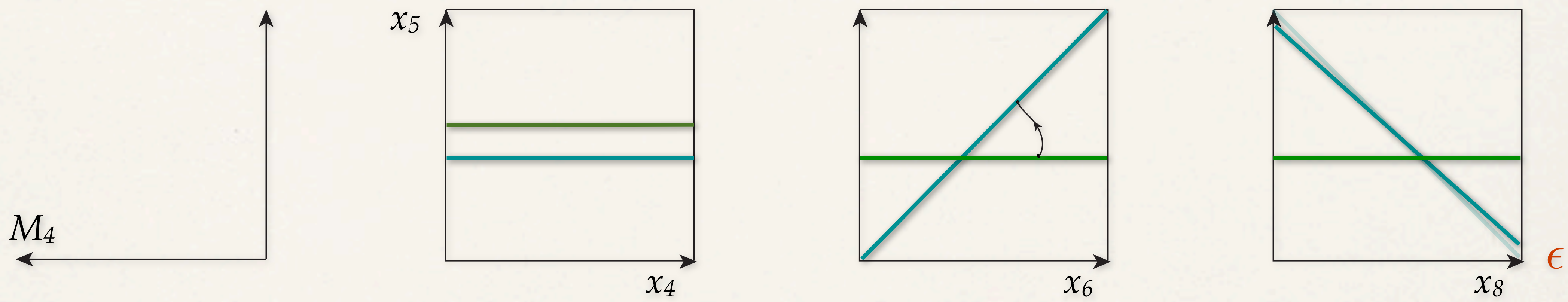

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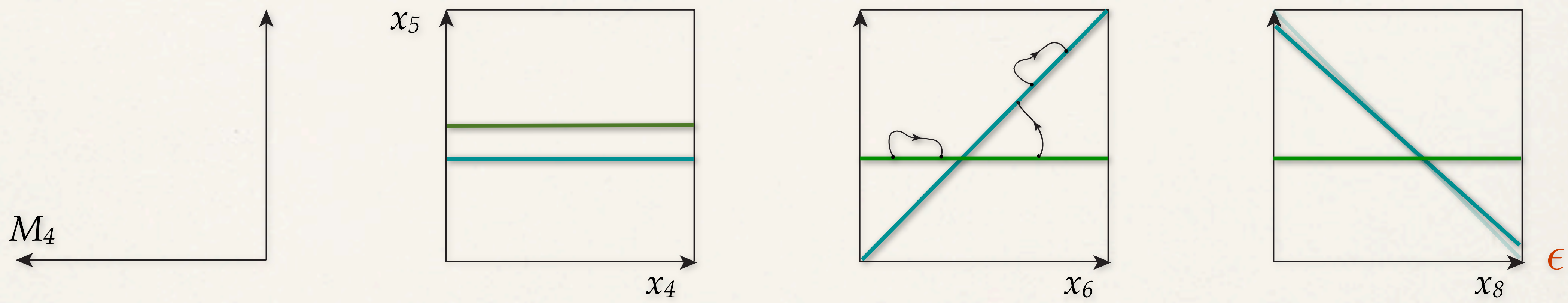

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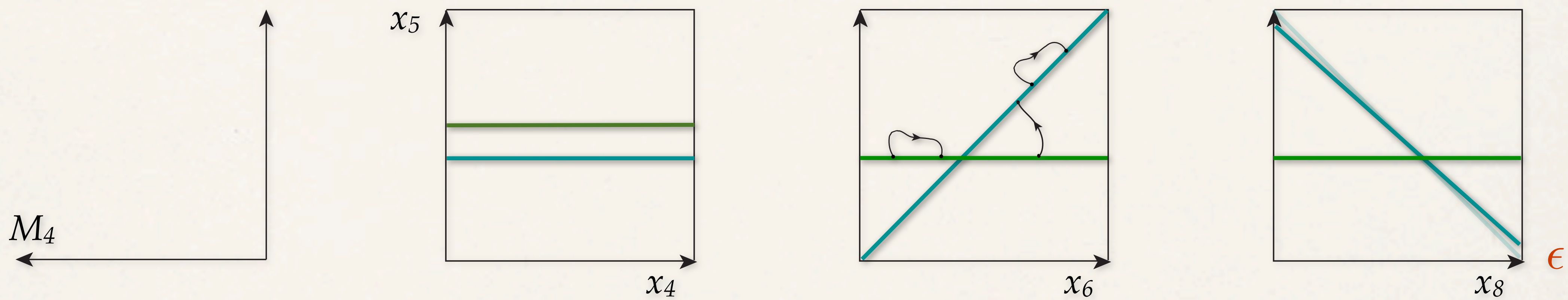

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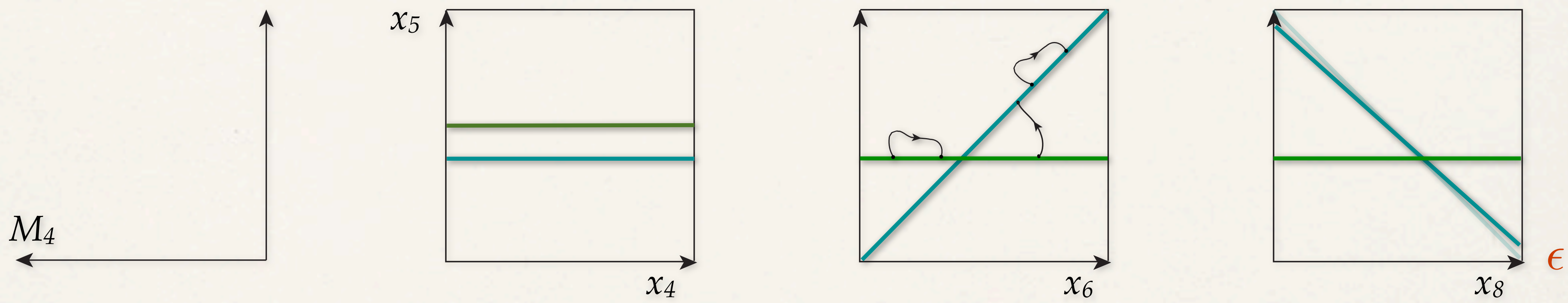

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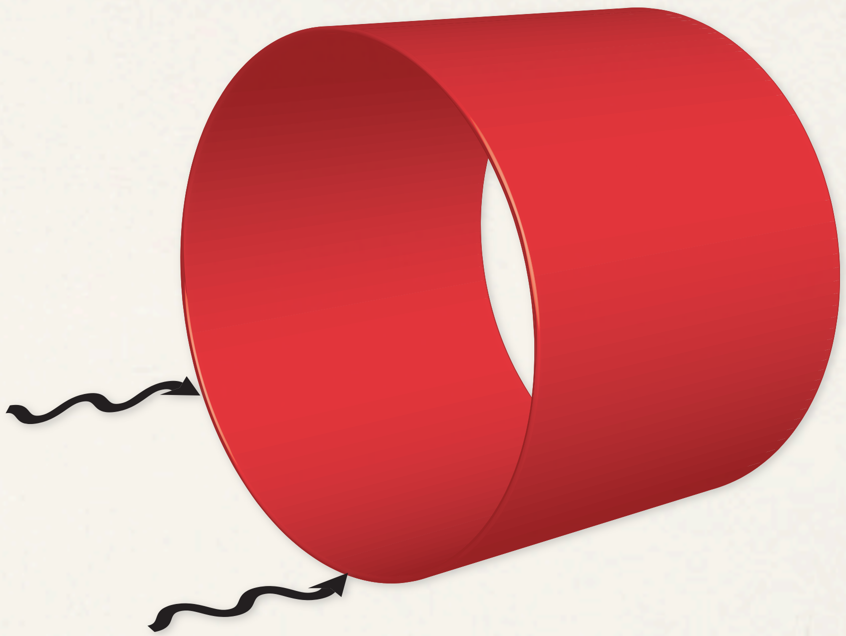
- The later will obtain masses at 1-loop due to couplings with the bi-fundamentals.



Amplitudes

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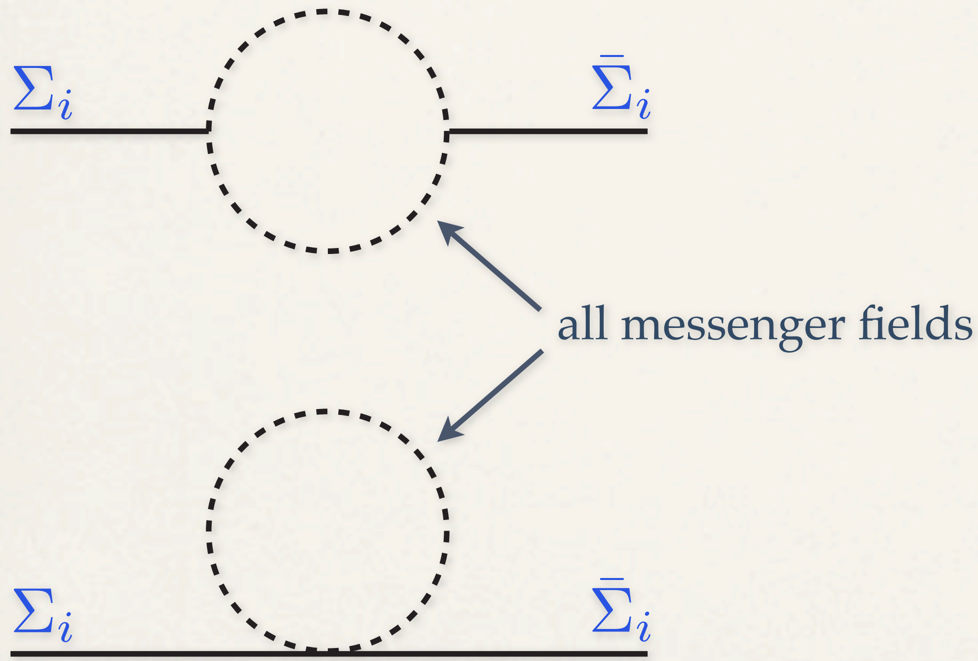

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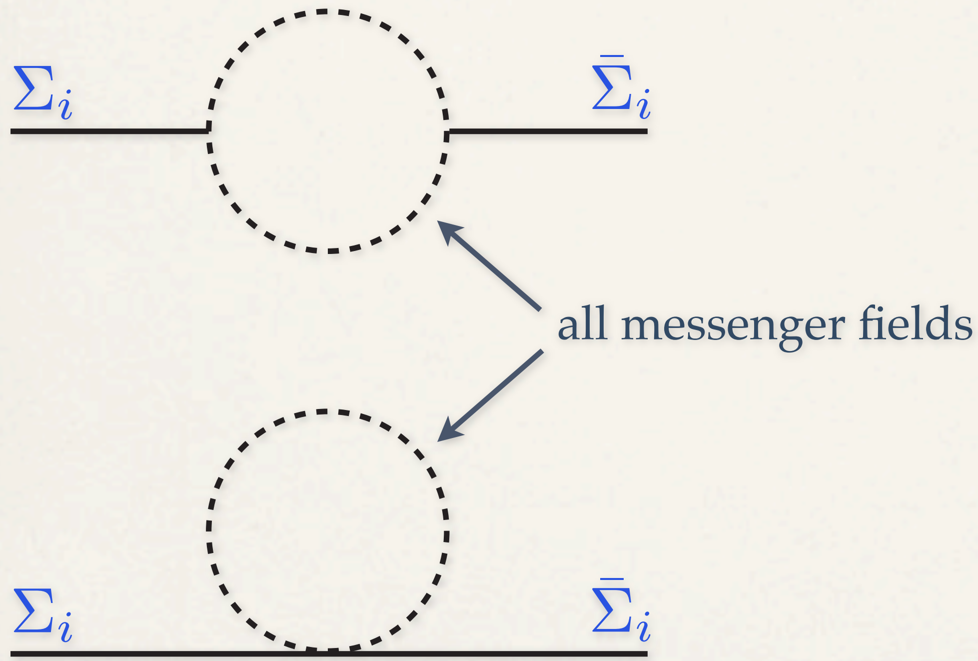

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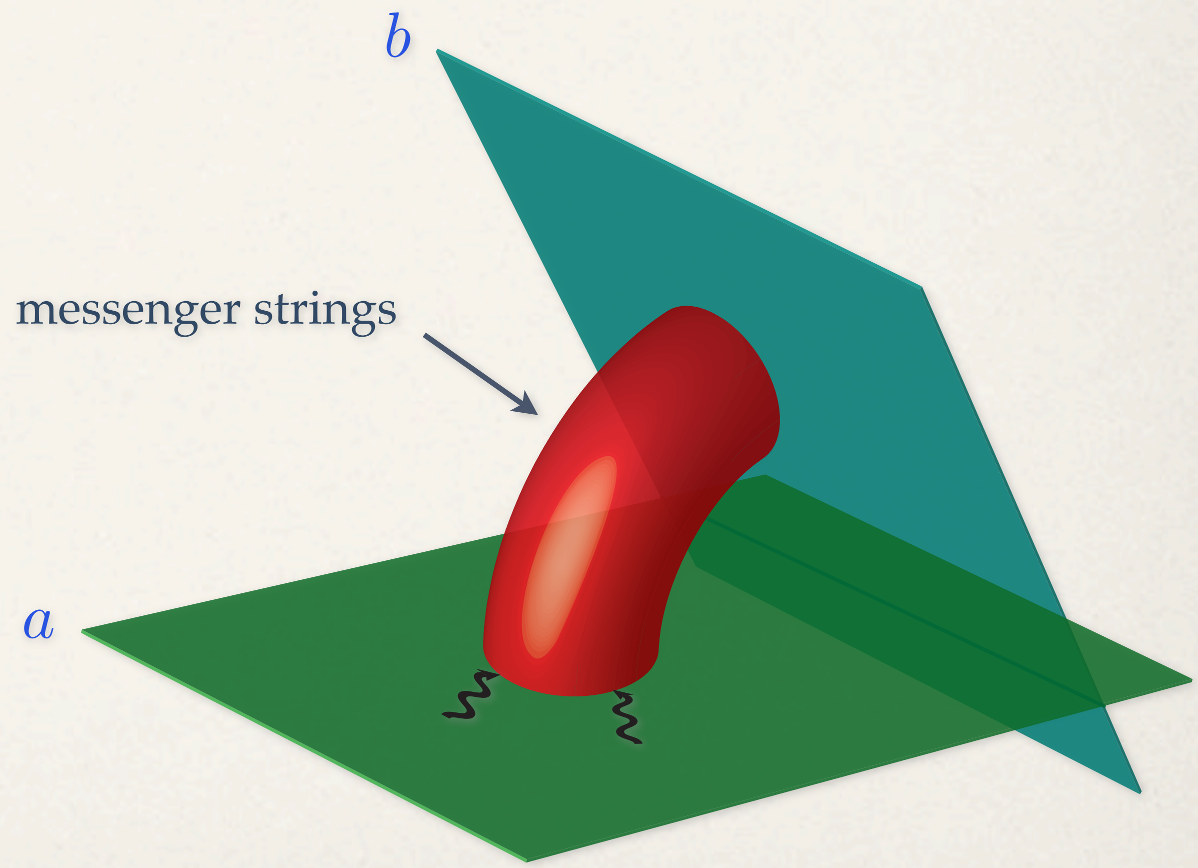

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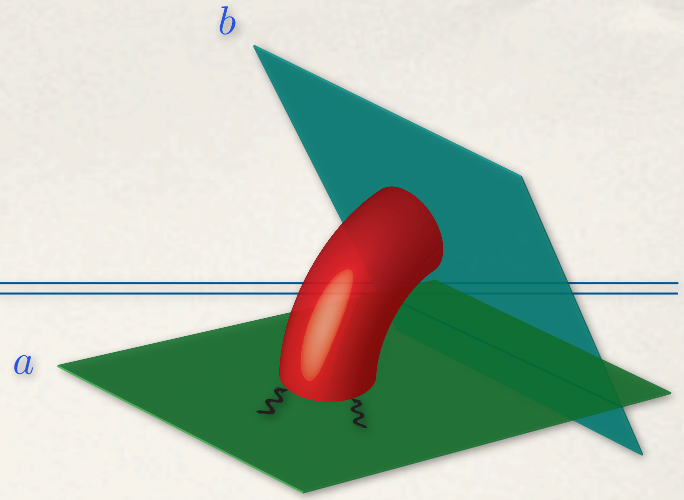
The computational techniques



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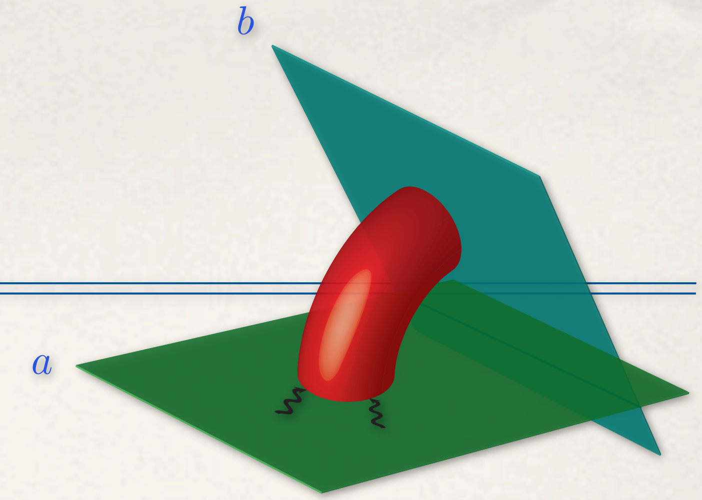
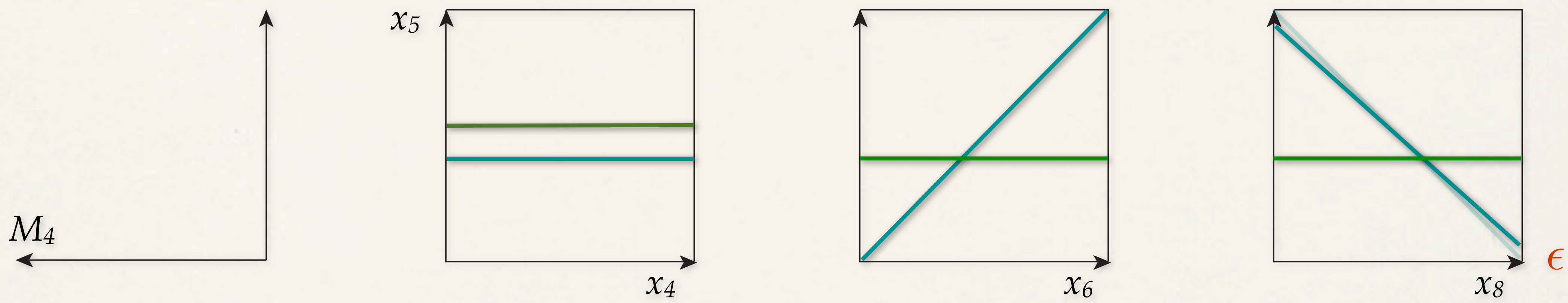


- In the above configurations, we have ($\mathcal{N} \approx 2$ for example):



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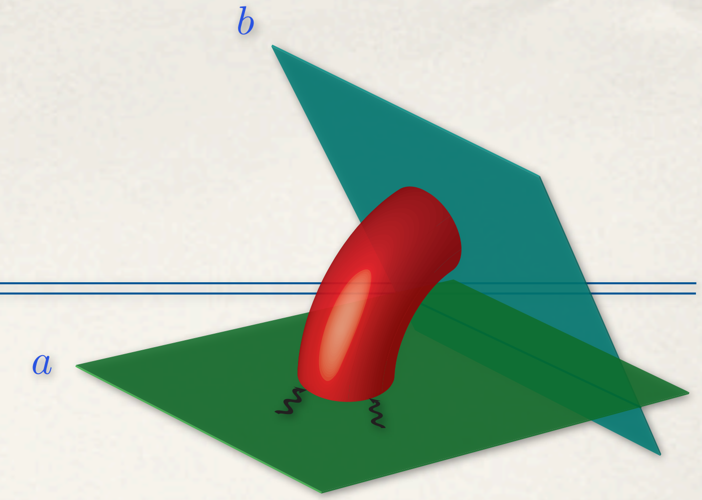

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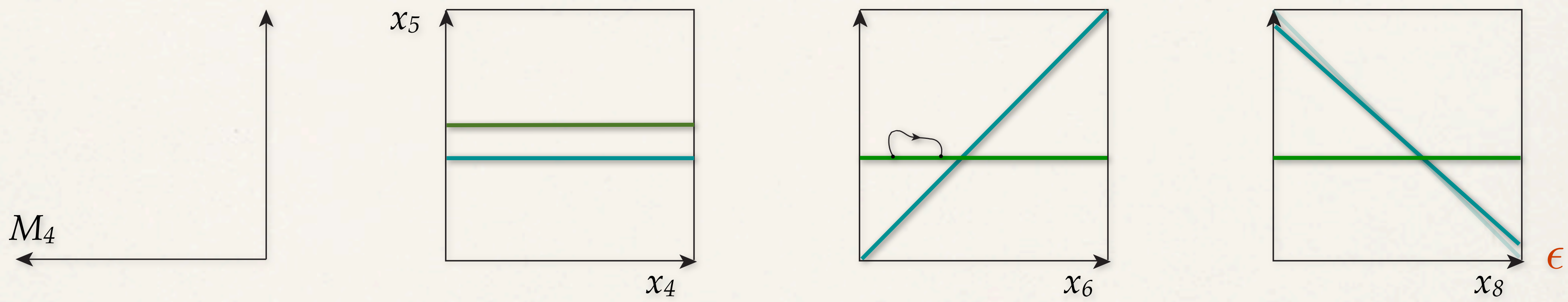

  - Adjoint scalars in non-parallel directions.

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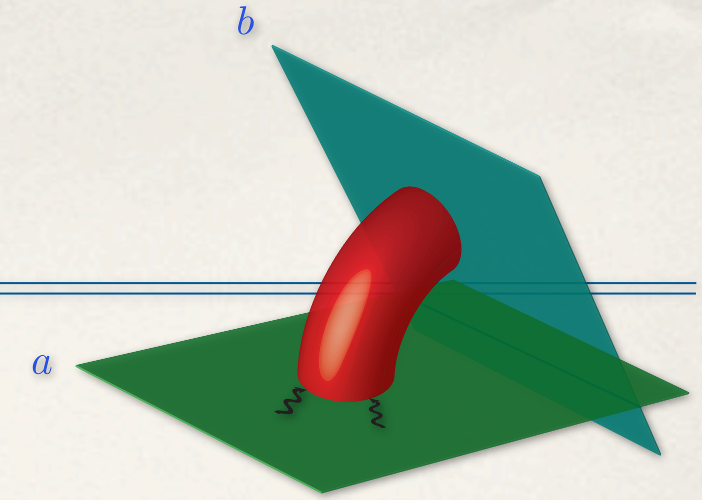

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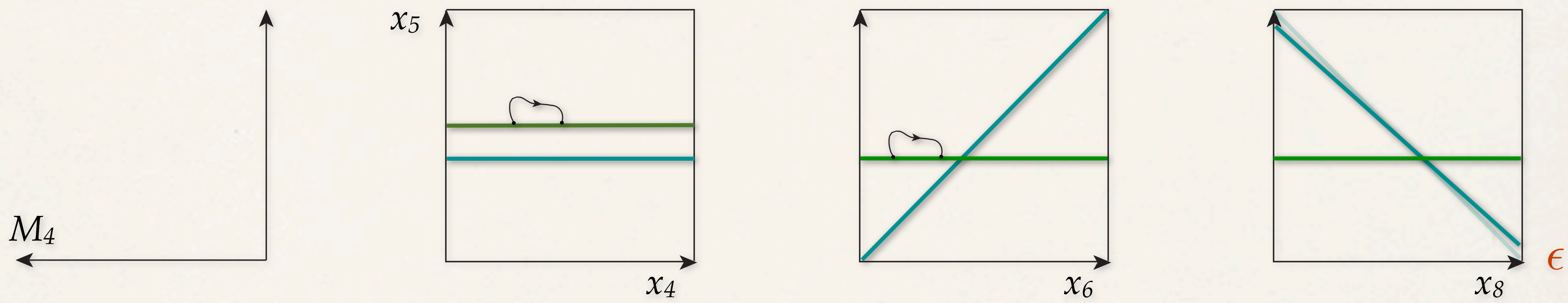

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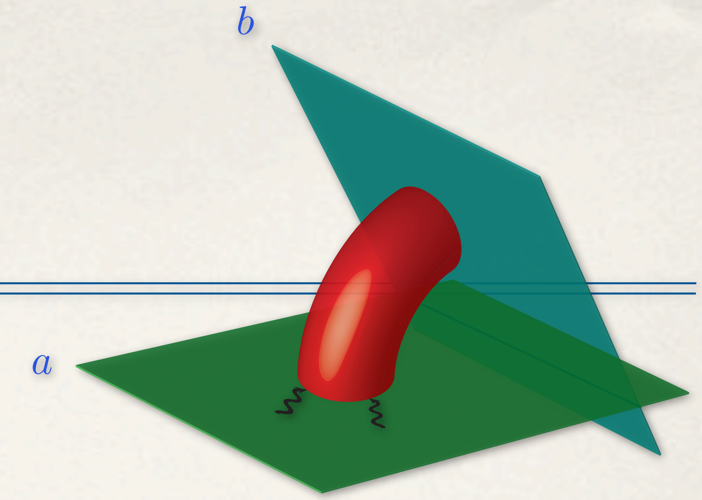

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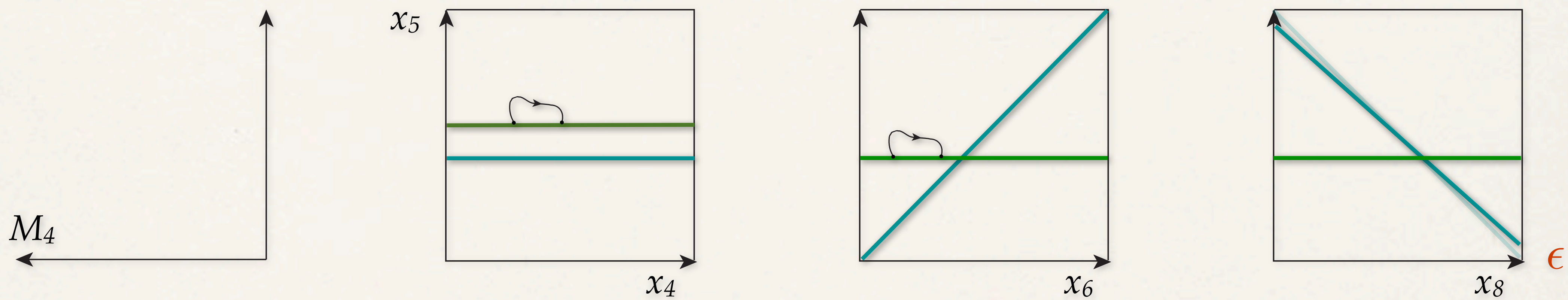

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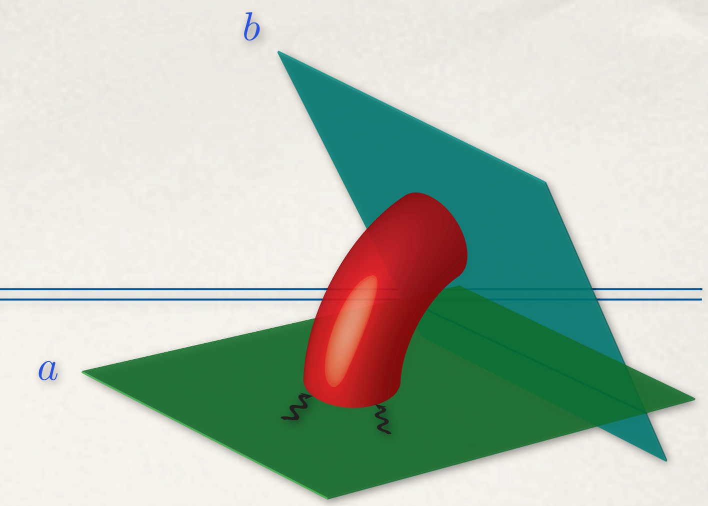

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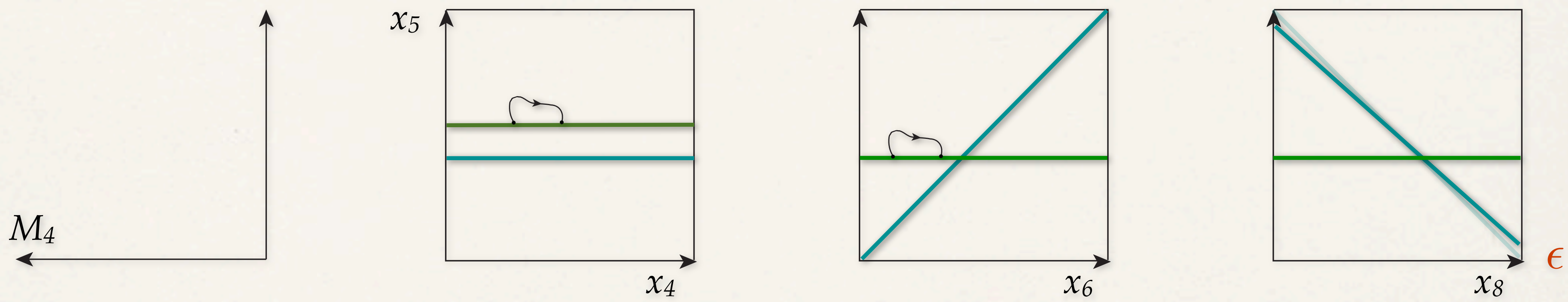

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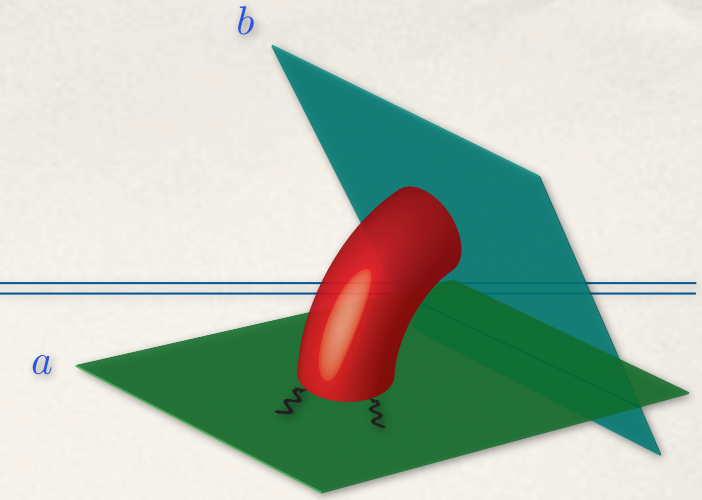

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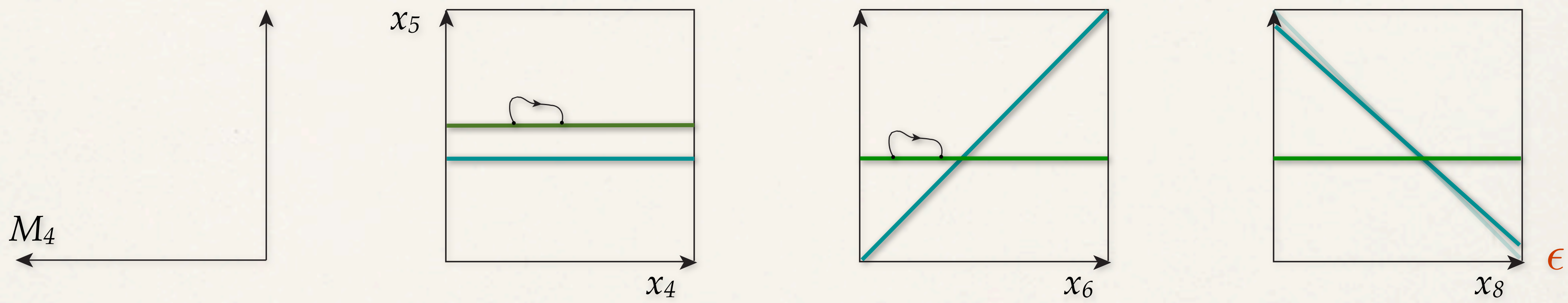

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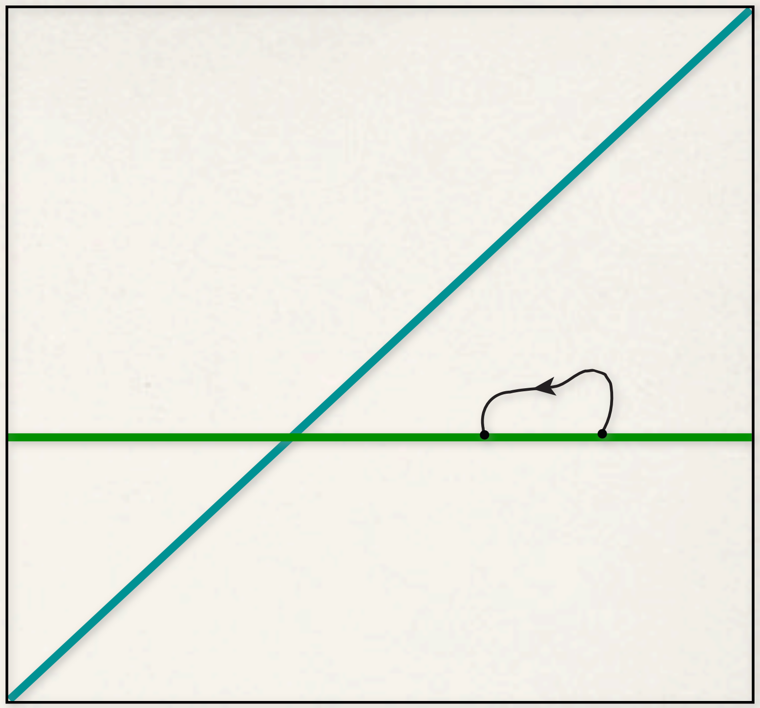
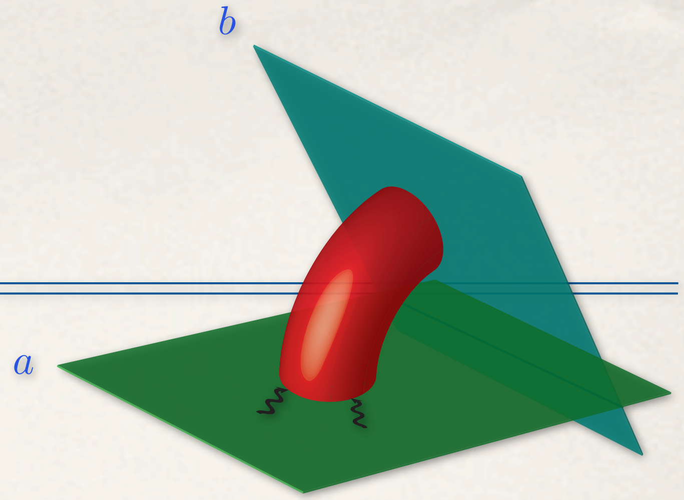
  - Computing the partition function in the presence of brane-displacements etc...



Adjoint masses for non-parallel dimensions

The amplitude method



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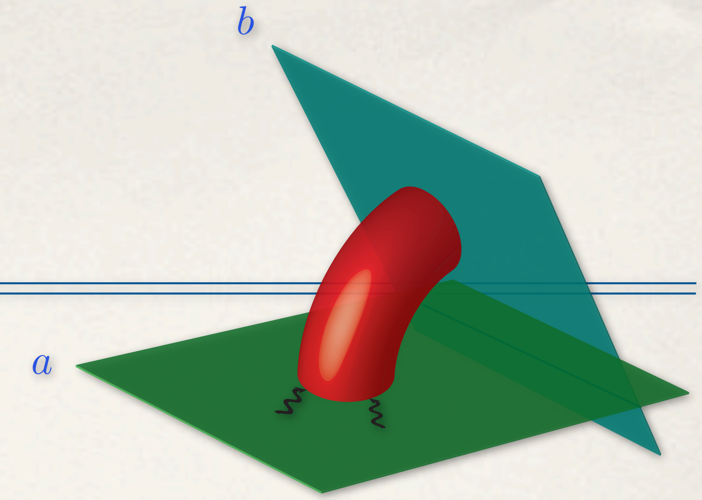

- The corresponding diagrams are:

$$\mathcal{A}_{\Sigma_3\Sigma_3} = ig^2 \int_0^\infty dt \int_0^{it/2} dz_1 \int_0^{it/2} dz_2 \int \frac{d^4p}{(2\pi)^4} Tr[V(k;z_1)V(k;z_2)e^{L_0}]$$

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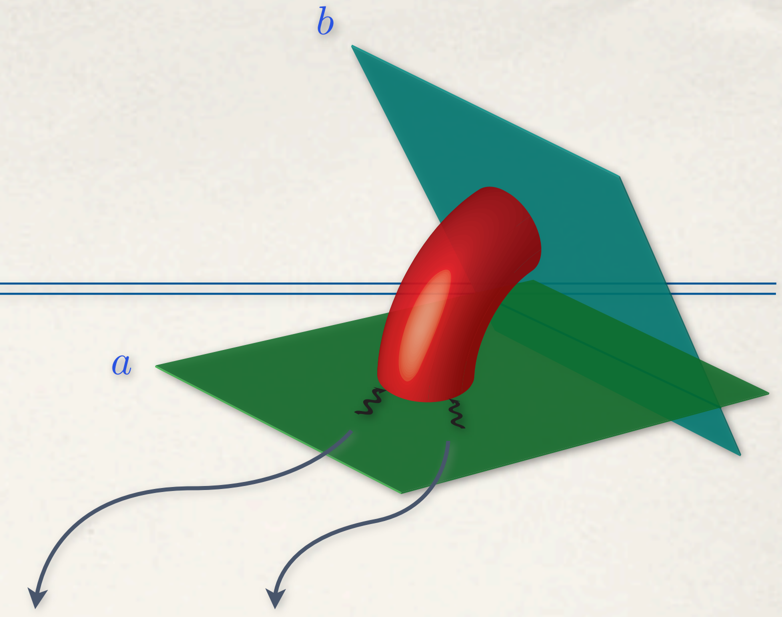

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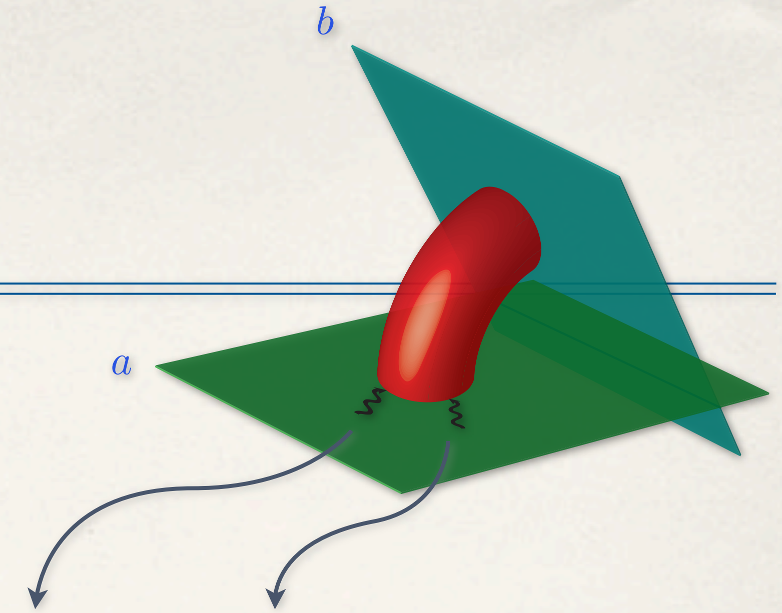

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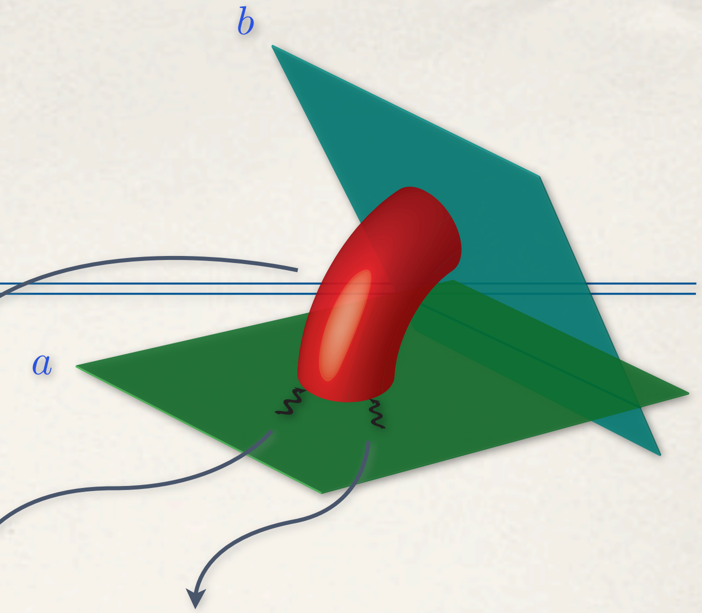

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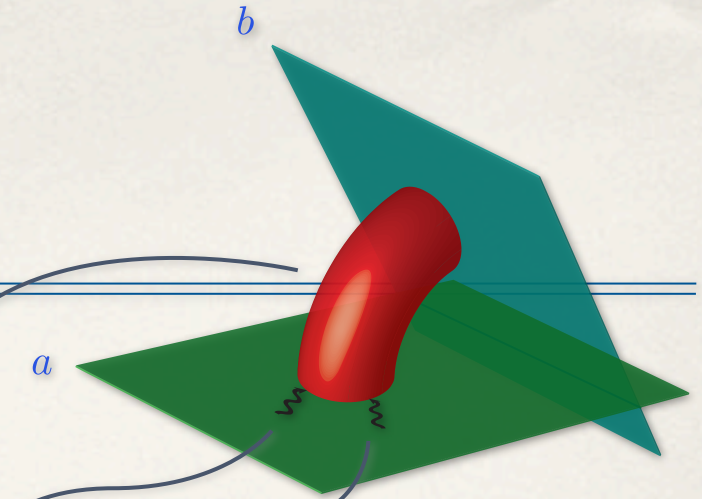

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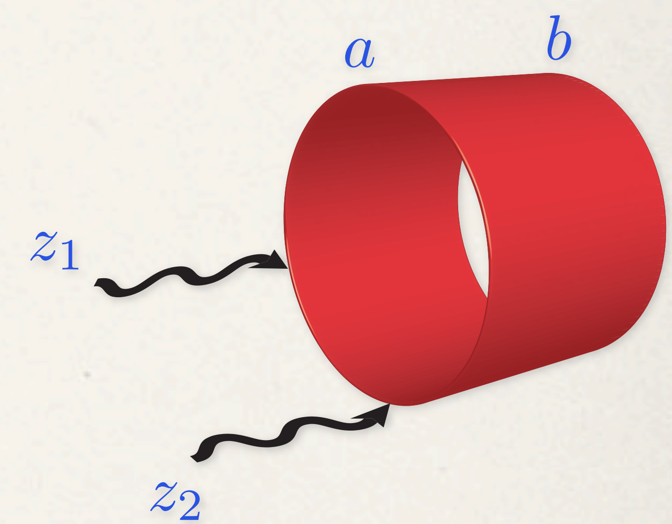

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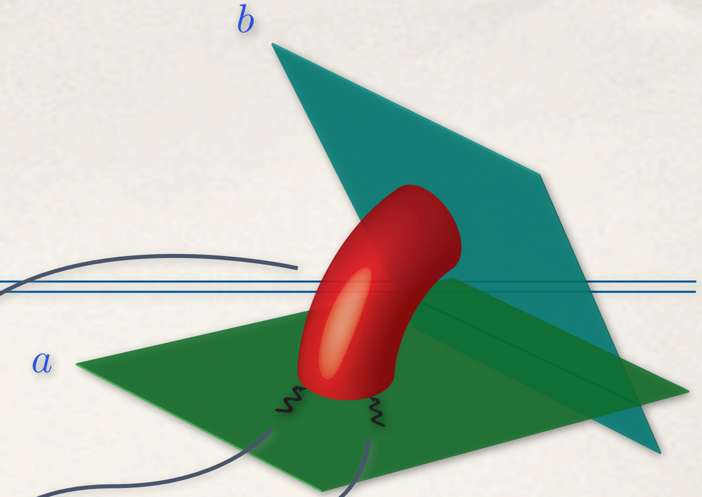

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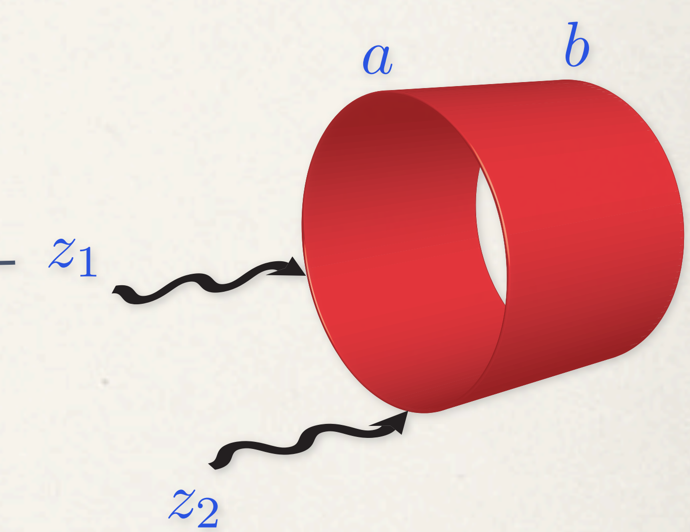

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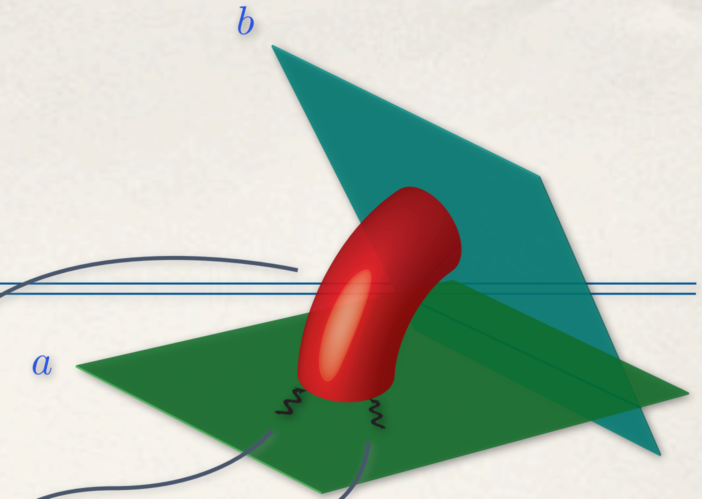

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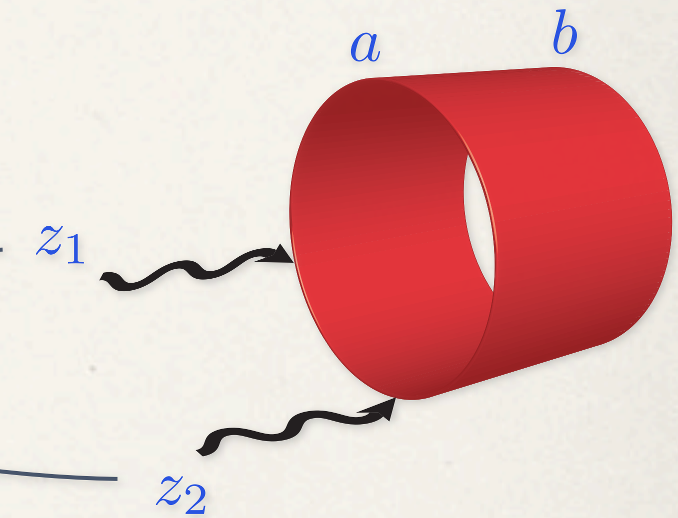

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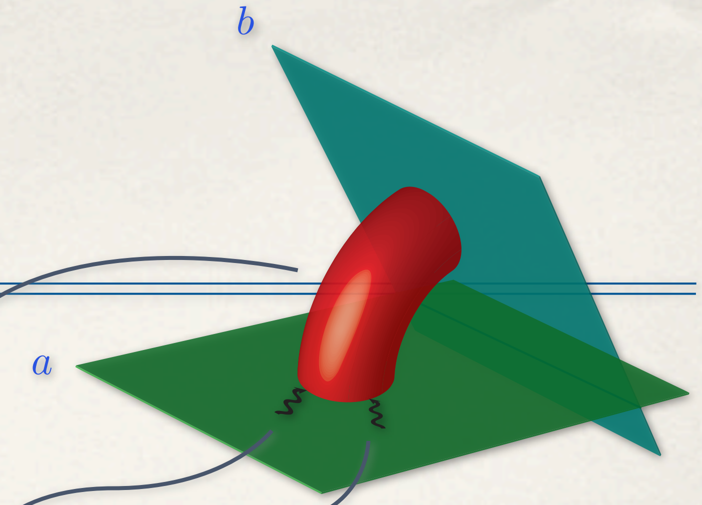

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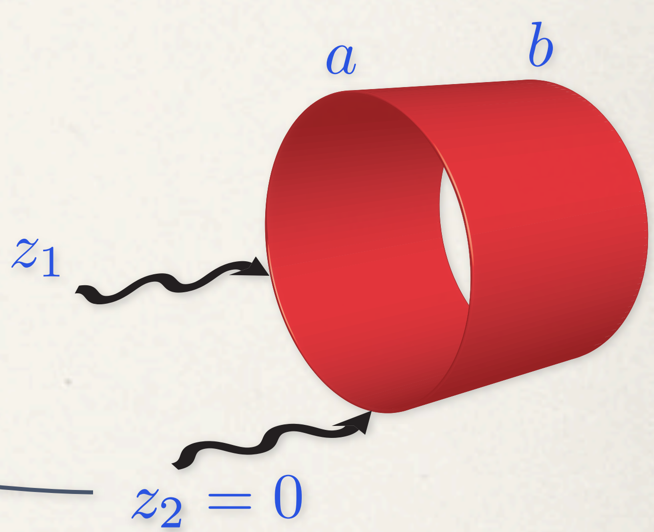

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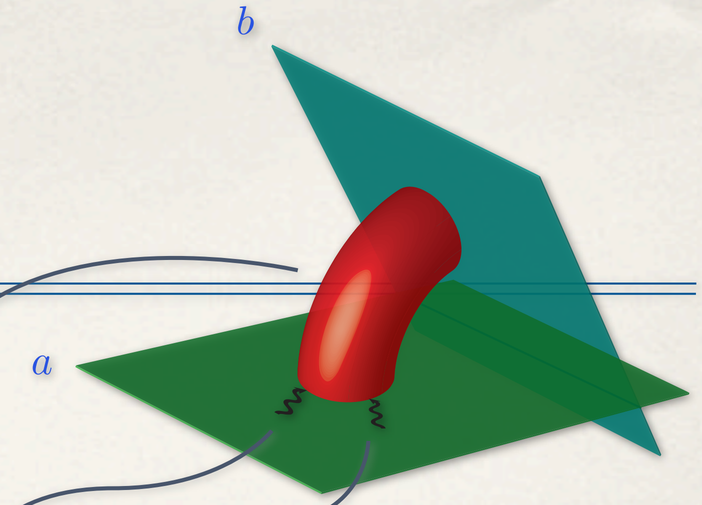

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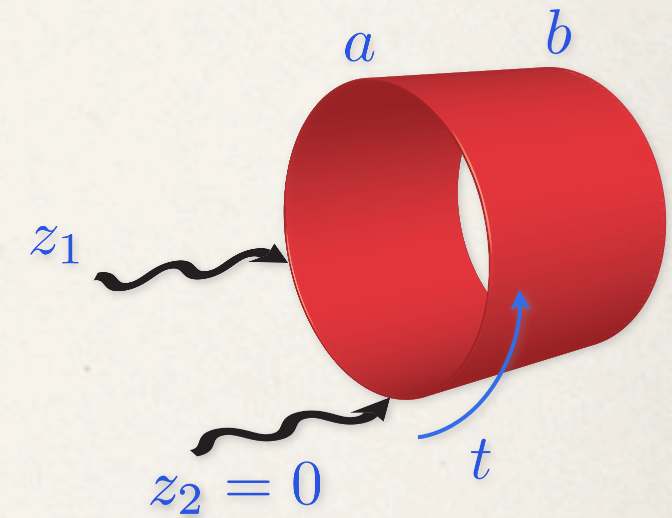

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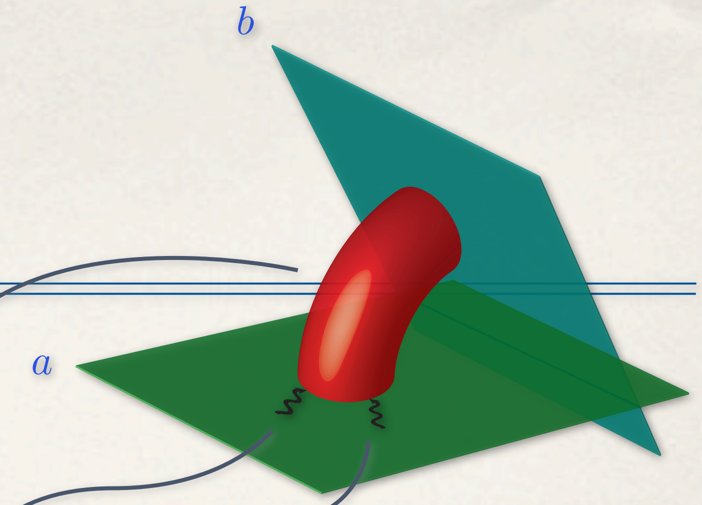

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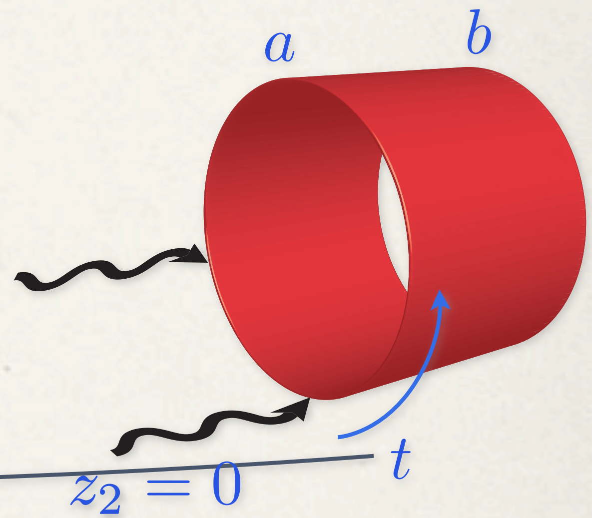

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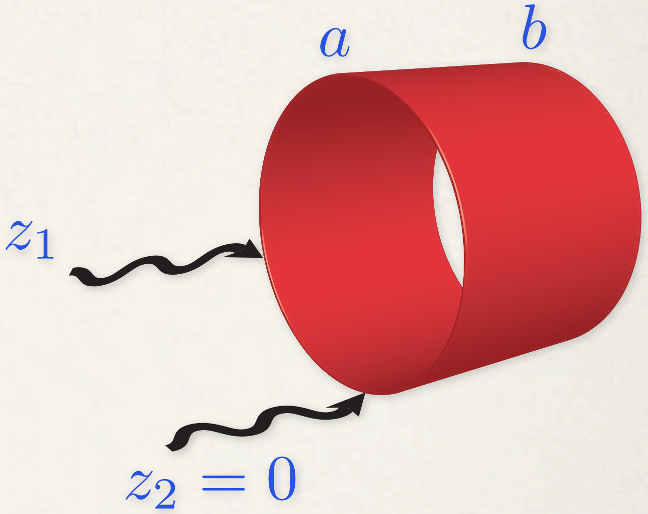

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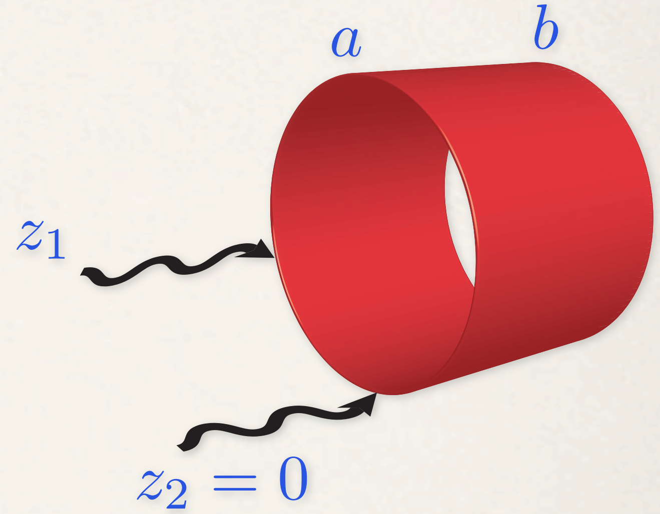

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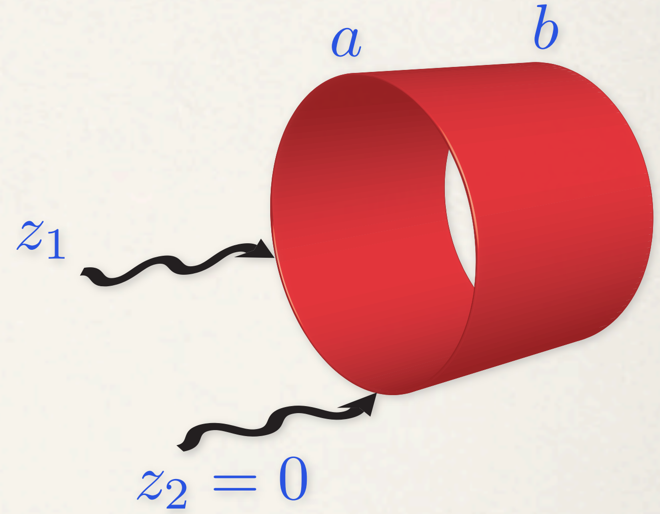

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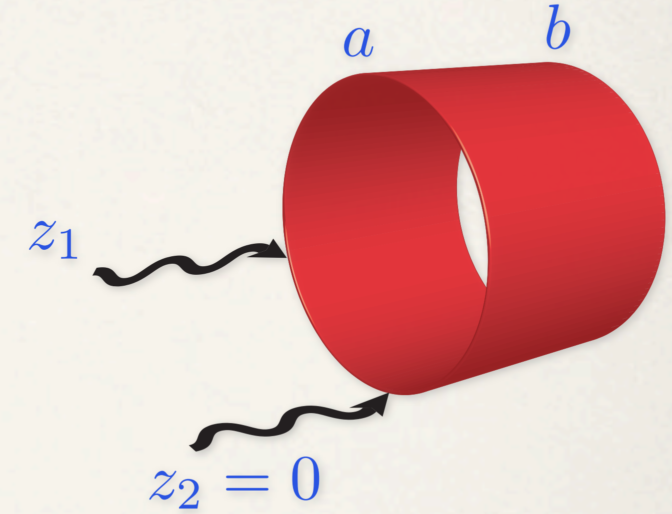

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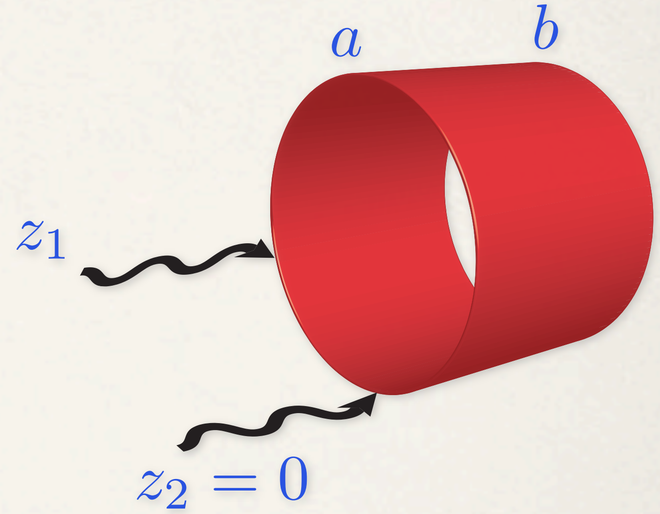

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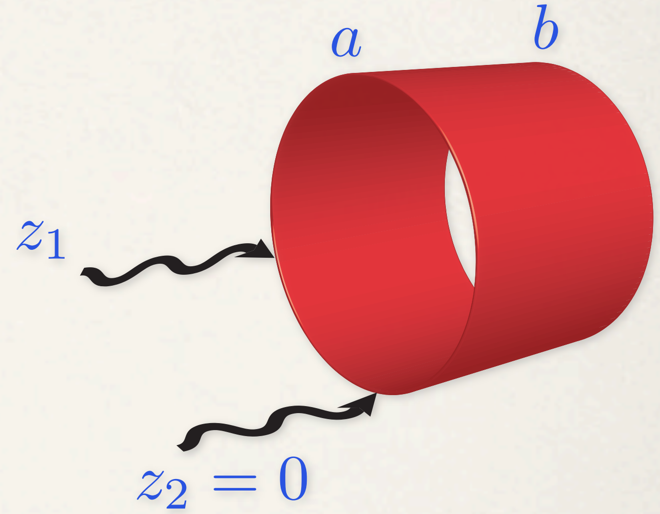

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- After several steps we get an expression only of well known $\vartheta_1(z, it/2)$'s.

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Bypassing difficulties

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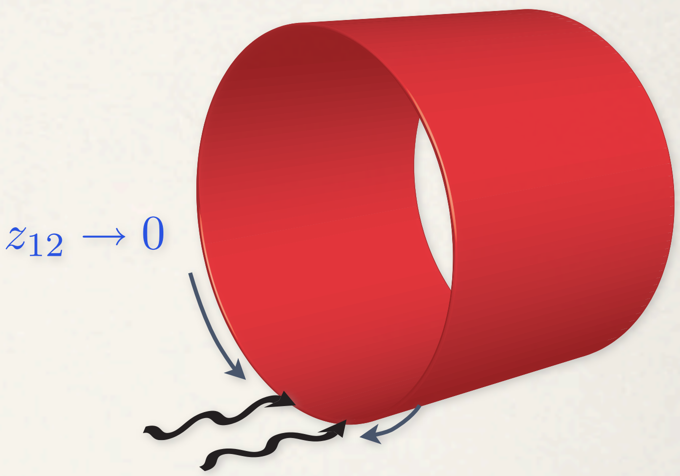
- String amplitudes generate mass terms due to:
  - World-sheet poles (integral on $z_{12} \to 0$):



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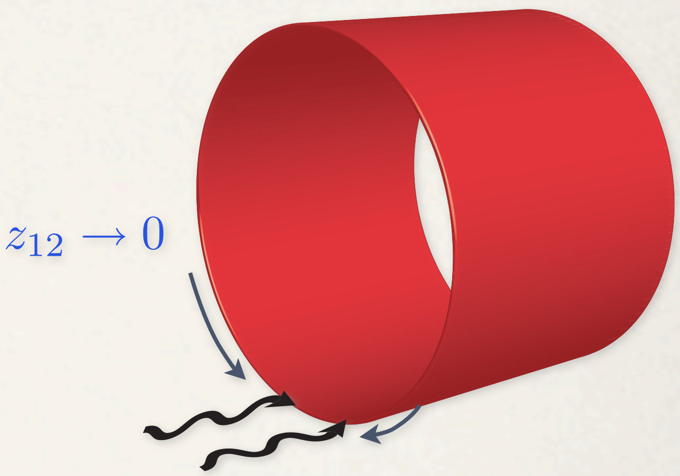

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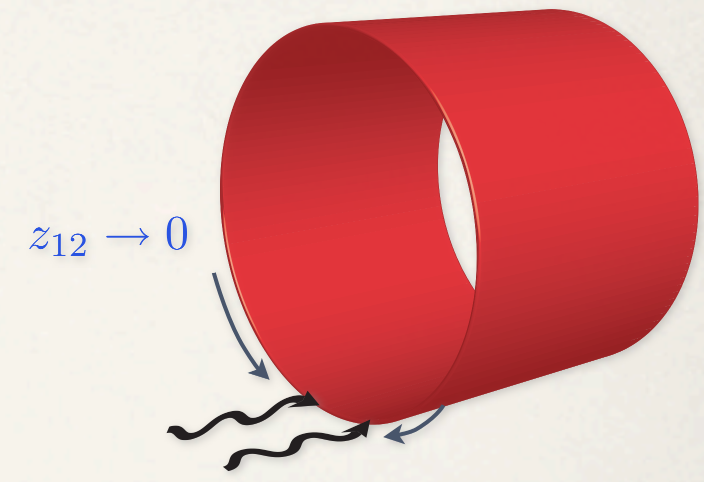

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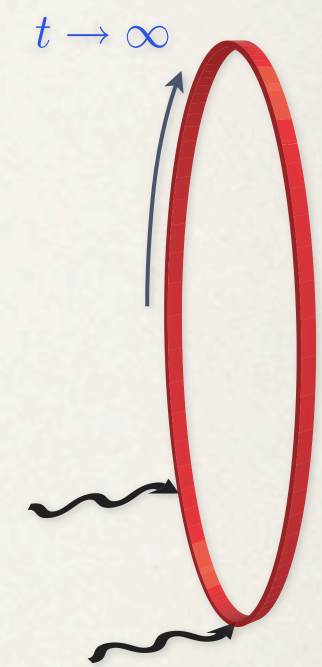

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Uncommon but might appear due to massless open string in the loop

Conlon Palti Goodsell

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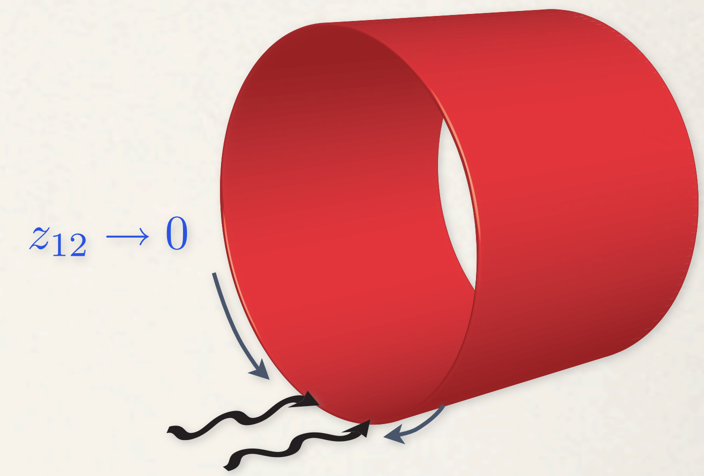

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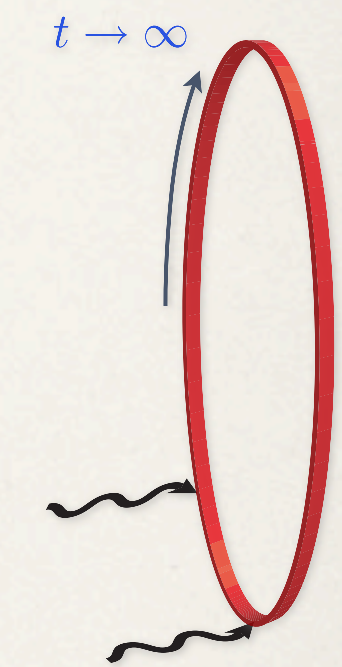

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Conlon Palti Goodsell

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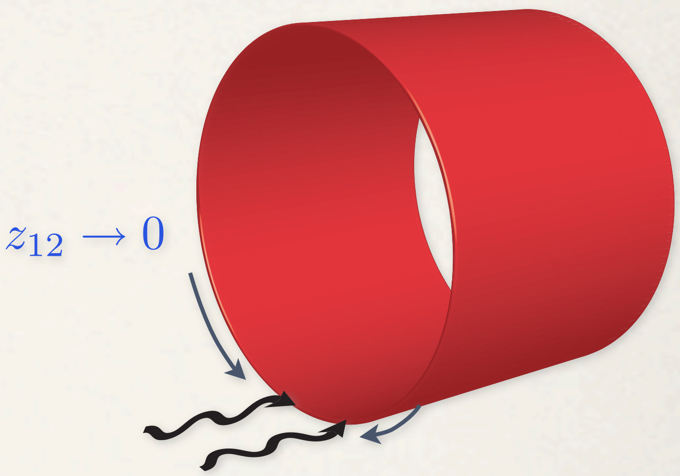
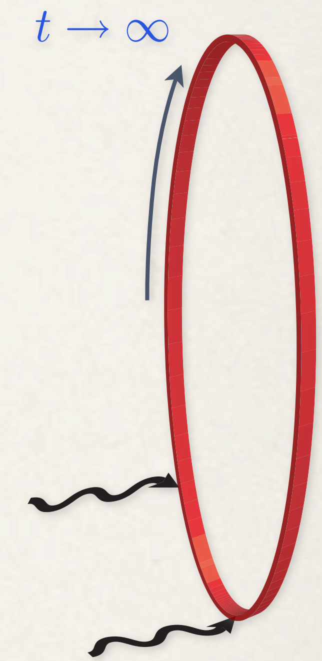


$$\mathcal{A} \sim k^2 \int dz_1 \left(\frac{\vartheta_1(z_1)}{\vartheta_1'(0)} \right)^{-1-2\alpha' k^2} \sim k^2 \int dz_1 \ (z_1)^{-1-2\alpha' k^2} \to \frac{1}{2\alpha'}$$

  - At the closed string UV (long strip limit $t \to \infty$):



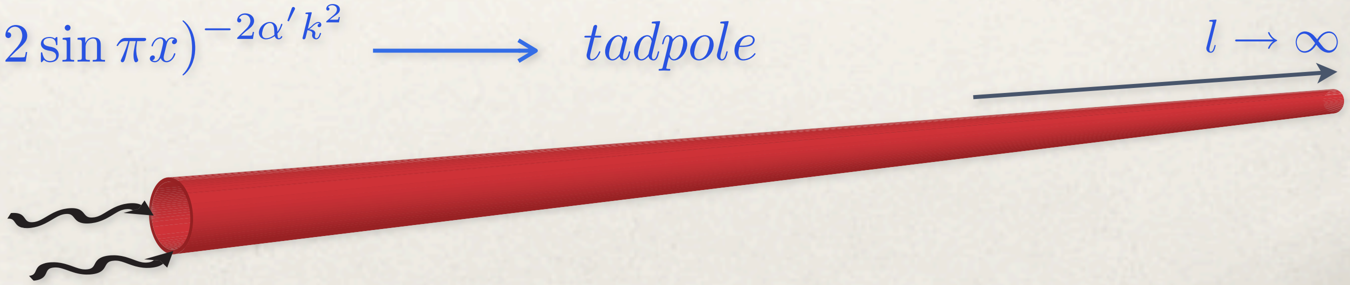
Uncommon but might appear due to massless open string in the loop

Conlon Palti Goodsell

  - At the closed string IR (long tube limit $t \to 0$):

$$\mathcal{A} \sim k^2 \int dl \ e^{-k^2 \langle XX \rangle (z_1)} \begin{cases} \text{opposite boundary} & k^2 \int_a^\infty dl \ e^{-\pi\alpha' k^2 l} \longrightarrow \frac{1}{\pi\alpha'} \\ \text{same boundary} & k^2 \int_a^\infty dl \ (2 \sin \pi x)^{-2\alpha' k^2} \longrightarrow \textit{tadpole} \end{cases}$$

Antoniadis Kiritsis Rizos, Anastasopoulos



Adjoint scalar masses

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- In our case,
  - There are no world-sheet poles. They cancel since our amplitude is even.
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$$\mathcal{A}_{\Sigma_3\bar{\Sigma}_3} = -\frac{ig^2}{16\pi^3\alpha'}\Big(\frac{\mathcal{V}_a^1\mathcal{V}_b^1}{T_2^1}\frac{\mathcal{V}_a^2\mathcal{V}_b^2}{T_2^2}\frac{\mathcal{V}_a^3\mathcal{V}_b^3}{T_2^3}\Big)\Big(-1+\cos^2[\pi\theta_1]+\cos^2[\pi\theta_2]-\cos^2[\pi\theta_3]\Big)$$

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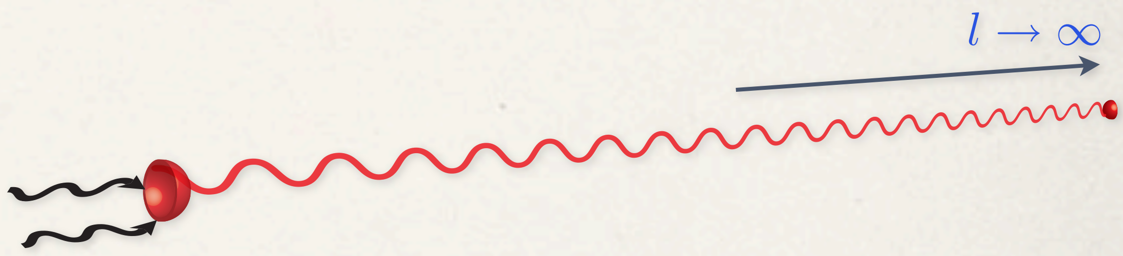

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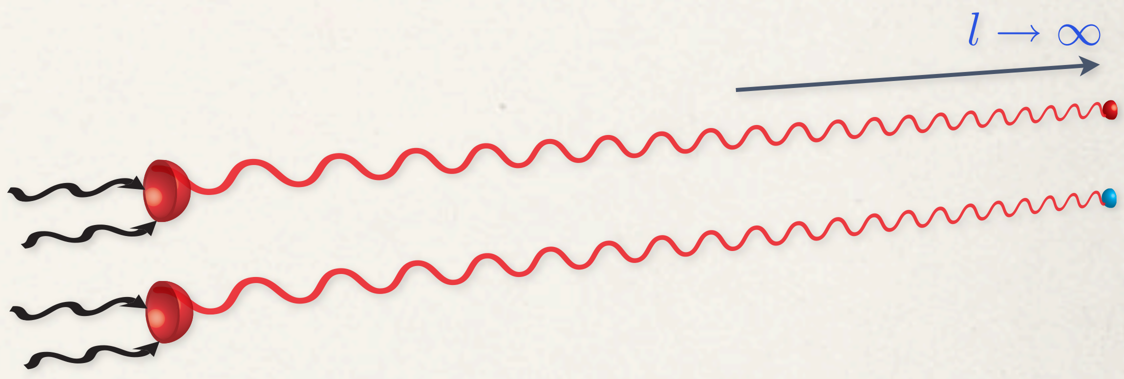

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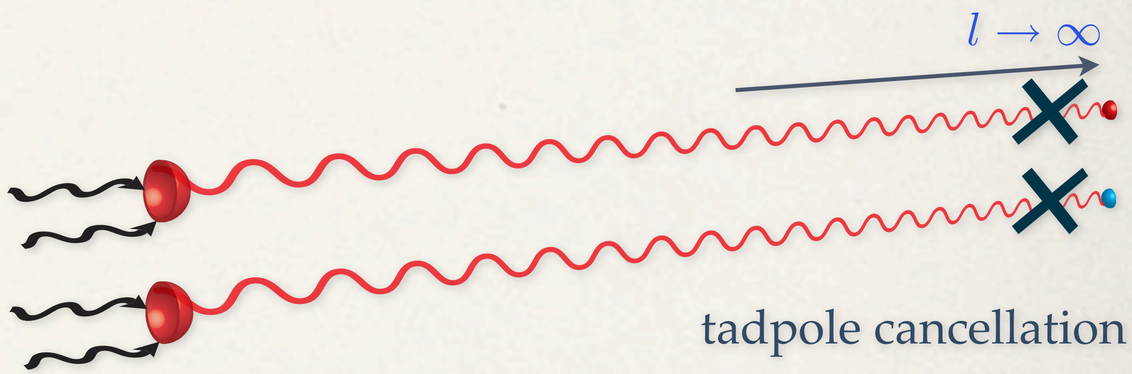

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Poppitz, Bain Berg

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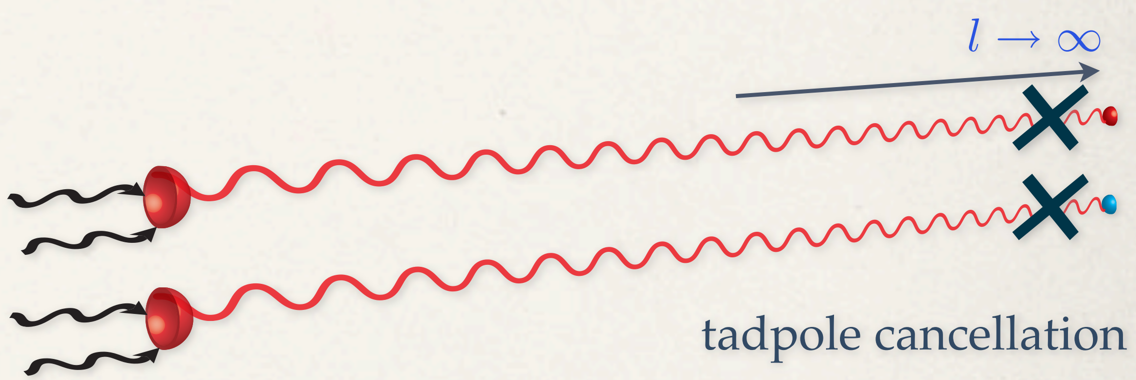

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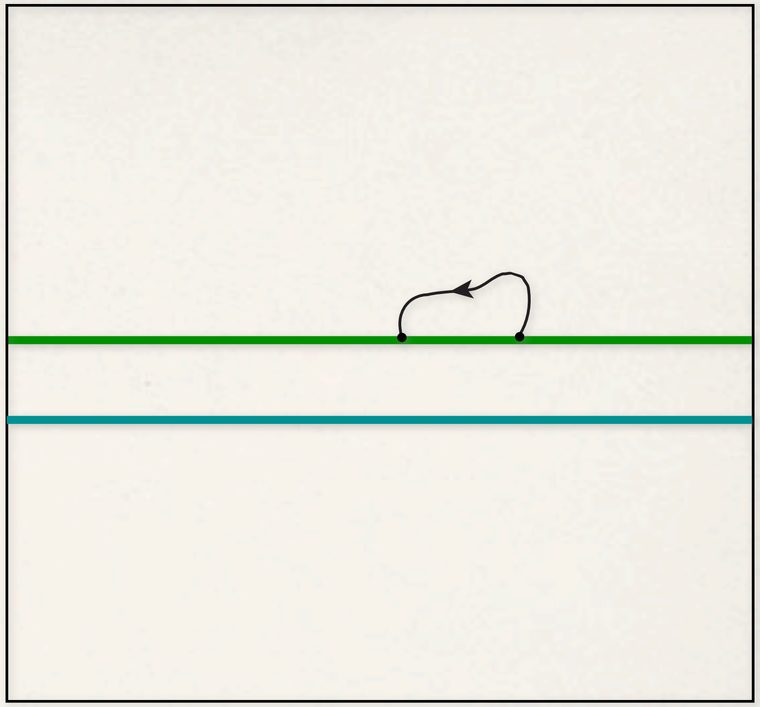
- We have checked that for the $Z_2 \times Z_2$ orientifold.



Adjoint masses for parallel dimensions

Effective potential

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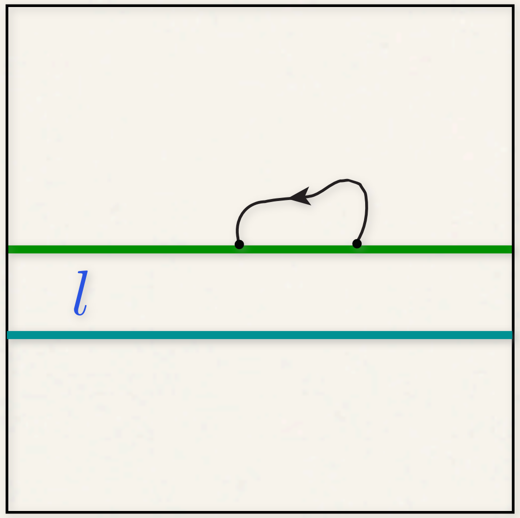

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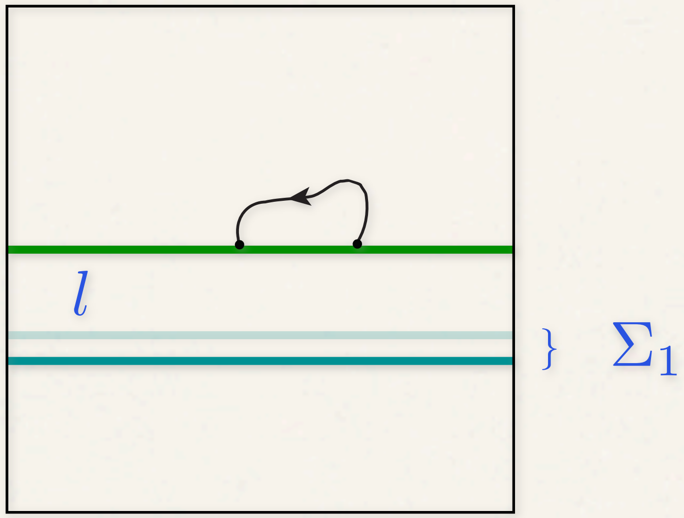

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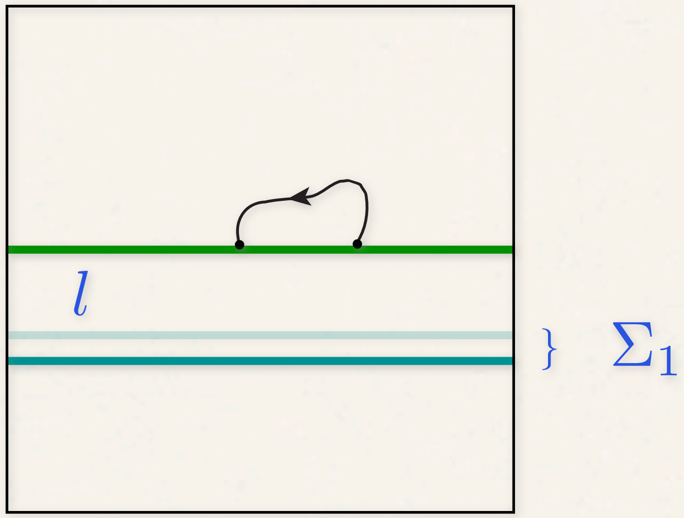

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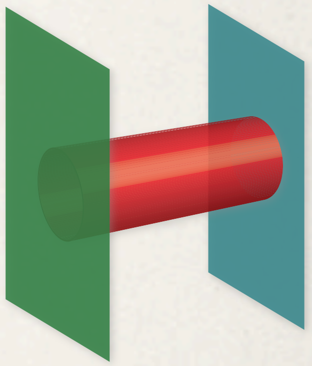

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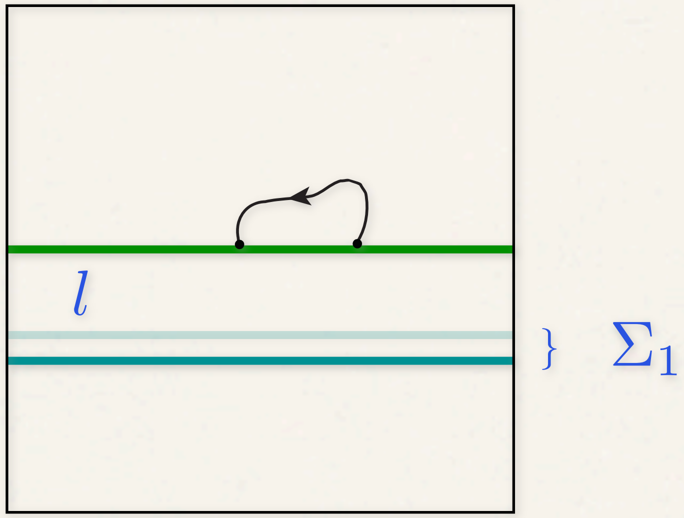

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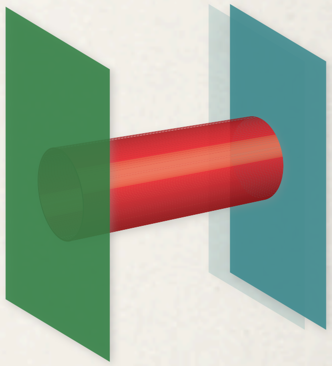

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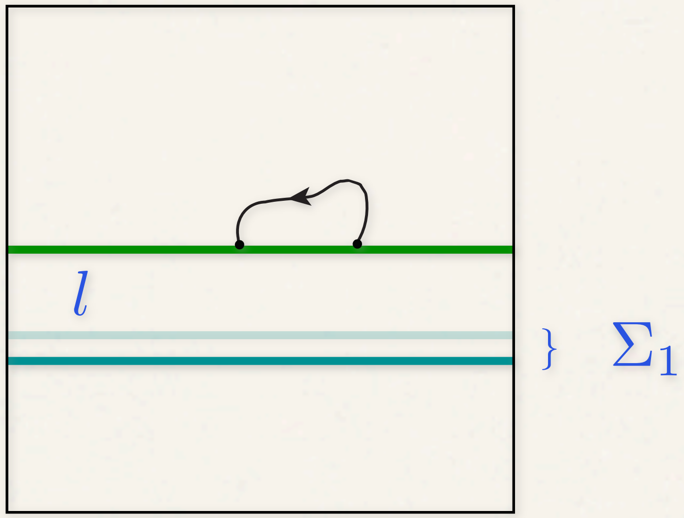

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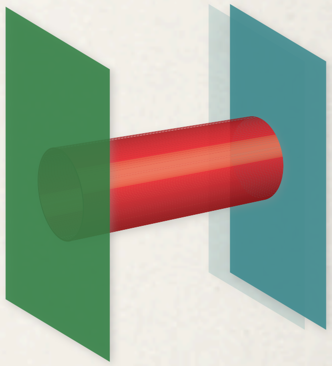

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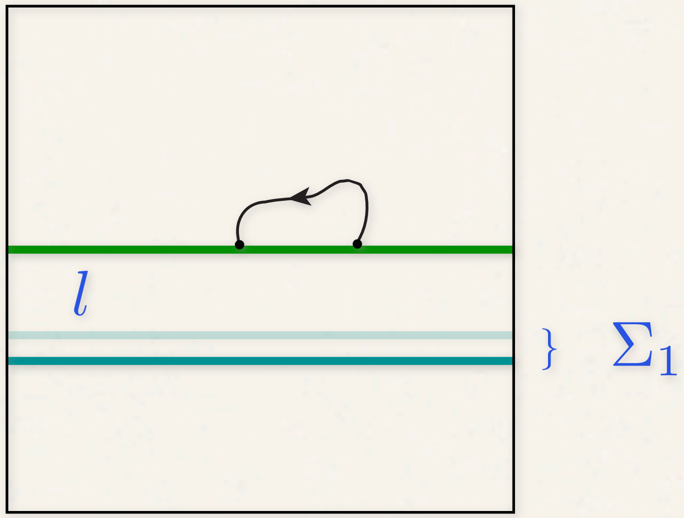

- We evaluate the partition function by displacing the branes by Σ_1, Σ_2.
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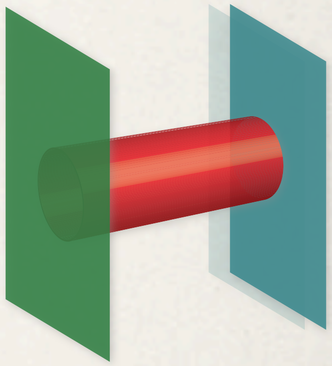
- The second derivatives will give the masses of windings and Wilson lines.
- That method is much simpler, but can only be performed for the $\mathcal{N} \approx 2{,}4$.



$\mathcal{N} \approx 2$ case

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- The potential for the $\mathcal{N} \approx 2$ case is:

$$V(\Sigma_1, \Sigma_2) = -64\pi^2\varepsilon^2 \sum_{m,n} \int \frac{dt}{t} e^{-2\pi t\left((\Sigma_1 + mR_{1,1})^2 + (\Sigma_2 + l + nR_{2,1})^2\right)}$$

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from where we can compute the tadpoles:

$$V^{(0,1)} \sim -32\pi^2\varepsilon^2 \sum_{m,n} \frac{l + nR_{2,1}}{(mR_{1,1})^2 + (l + nR_{2,1})^2} \neq 0$$

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$$V^{(0,2)} \sim -32\pi^2\varepsilon^2 \sum_{m,n} \frac{(mR_{1,1})^2 - (l + nR_{2,1})^2}{\left[(mR_{1,1})^2 + (l + nR_{2,1})^2\right]^2} \geq 0$$

$$V^{(1,1)} \sim \ \ 64\pi^2\varepsilon^2 \sum_{m,n} \frac{(mR_{1,1})\,(l + nR_{2,1})}{\left[(mR_{1,1})^2 + (l + nR_{2,1})^2\right]^2} \to 0$$

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} tachyon

$$V^{(1,1)} \sim 64\pi^2\varepsilon^2 \sum_{m,n} \frac{(mR_{1,1})(l + nR_{2,1})}{\left[(mR_{1,1})^2 + (l + nR_{2,1})^2\right]^2} \to 0$$

$\mathcal{N} \approx 4$ case

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- The potential for the $\mathcal{N} \approx 4$ case is:

$$V(\Sigma_{1,i},\ \Sigma_{2,i}) \sim -4\pi^2\varepsilon^3 \left(\sum_{i=1,2} \left((\Sigma_{1,i} + \tilde{n}_i R_{1,i})^2 + (\Sigma_{2,i} + l_i + n_i R_{2,i})^2 \right) \right)^{-1}$$

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- The tadpoles in this case:

$$\begin{aligned}
V^{(1,0,0,0)} &\sim 8\pi^2\varepsilon^3 \sum_{\tilde{n},n} \frac{\tilde{n}_1 R_{1,1}}{\left(\sum_i \left((\tilde{n}_i R_{1,i})^2 + (l_i + n_i R_{2,i})^2\right)\right)^2} \to 0 \\
V^{(0,1,0,0)} &\sim 8\pi^2\varepsilon^3 \sum_{\tilde{n},n} \frac{l_1 + n_2 R_{2,1}}{\left(\sum_i \left((\tilde{n}_i R_{1,i})^2 + (l_i + n_i R_{2,i})^2\right)\right)^2} \neq 0 \\
V^{(0,0,1,0)} &\sim 8\pi^2\varepsilon^3 \sum_{\tilde{n},n} \frac{\tilde{n}_2 R_{1,2}}{\left(\sum_i \left((\tilde{n}_i R_{1,i})^2 + (l_i + n_i R_{2,i})^2\right)\right)^2} \to 0 \\
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\end{aligned}$$

which can be cancelled by properly choosing image branes.

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- The adjoints masses:

$$V^{(2,0,0,0)}|_{a_{i,j}\to 0} \sim 16i\pi^2\varepsilon^3 \sum_{\tilde{n},n} \frac{-4(\tilde{n}_1 R_{1,1})^2 + S[\tilde{n},n]}{S[\tilde{n},n]^3} \neq 0$$

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where: $S[\tilde{n},n] = (\tilde{n}_1 R_{1,1})^2 + (l_1 + n_1 R_{2,1})^2 + (\tilde{n}_2 R_{1,2})^2 + (l_2 + n_2 R_{2,2})^2$.

$\mathcal{N} \approx 4$ case

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- Schematically, the mass-matrix for the adjoints is:

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- Therefore, there is at least one tachyonic state.

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- We consider breaking of supersymmetry in intersecting D-brane configurations by slight deviation of the angles from their supersymmetric values.
- We compute the masses generated by radiative corrections for the adjoint scalars on the brane world-volumes.
- In the open string channel, the string two-point function receives contributions only from the infrared ($\mathcal{N} \approx 2$,4) and the ultraviolet limits ($\mathcal{N} \approx 1$).
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- On the other hand, the infrared region ($\mathcal{N} \approx 2$,4) reproduces the one-loop mediation of supersymmetry breaking in the effective gauge theory, via messengers and their Kaluza-Klein excitations.

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- Tachyons might be cancelled in models with Scherk-Schwarz deformations...

work in progress...