Beyond the tensionless limit

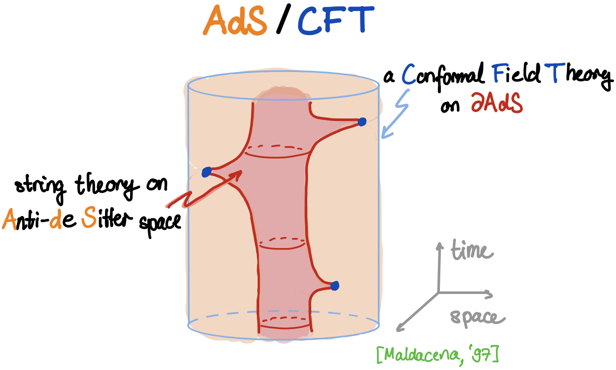
Beat Nairz

25 November 2025

based on **2312.13288**[△], **2411.17612**[□], **2412.02741**[◇]

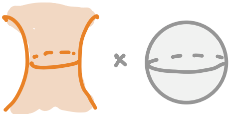
with Matthias R. Gaberdiel[△,□,◇], Rajesh Gopakumar[△], Dennis Kempel[◇] and Felix Lichtner[□]

ETH zürich



- Context: AdS_3/CFT_2
- Goal: understand perturbation of minimal tension point (exact duality!)

Two examples of AdS/CFT



$AdS_5 \times S^5$

↕

$\mathcal{N}=4$ super Yang Mills

in 4 dimensions

(cousin of QCD)

$AdS_3 \times S^3 \times T^4$

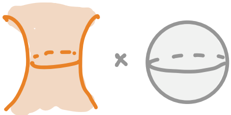
↕

"D1-D5" CFT

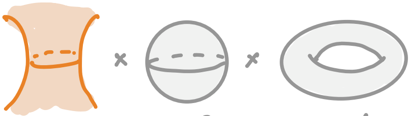
in 2 dimensions

(symmetric orbifold)

Two examples of AdS/CFT



$AdS_5 \times S^5$



$AdS_3 \times S^3 \times T^4$

- \+ checks using integrability
- − poor understanding of mechanism underlying duality

$\mathcal{N}=4$ super Yang Mills in 4 dimensions

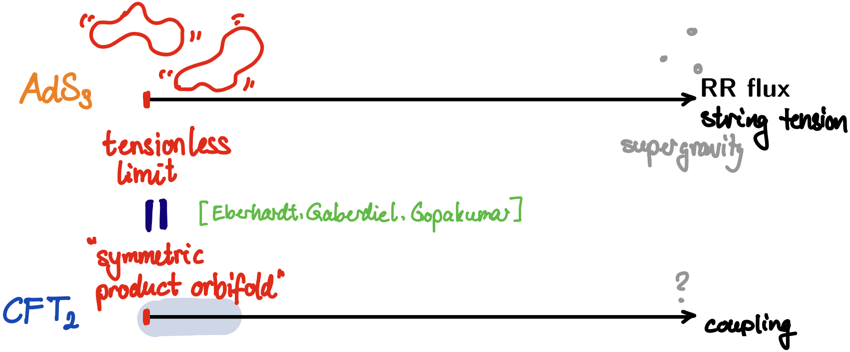
(cousin of QCD)

- \+ special case: mechanism understood / proven
- − integrability methods less powerful

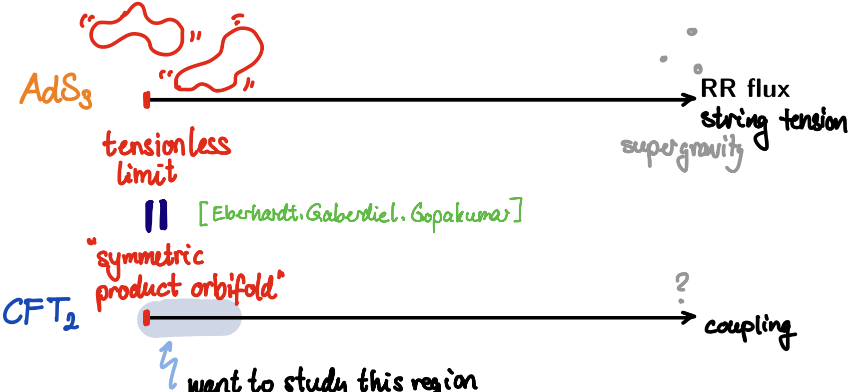
"D1-D5" CFT in 2 dimensions

(symmetric orbifold)

Exact duality



Exact duality



want to study this region

↳ make use of known mechanism; implications for duality at generic point

↳ find integrability in CFT ?

Overview – Perturbation

Turning on **string tension** $\longleftrightarrow$ **perturbation** of orbifold CFT

One thing to understand: **spectrum** (anomalous dimensions) and **eigenvectors**

Overview – Perturbation

Turning on **string tension** $\longleftrightarrow$ **perturbation** of orbifold CFT

One thing to understand: **spectrum** (anomalous dimensions) and **eigenvectors**

We study the perturbation and find simplified description: **integrable off-shell algebra** in BMN limit

By looking at eigenstates, we can also identify **geometric directions** in the CFT

Analytic continuation

$|\phi\rangle = \boldsymbol{X_1(p_1)\cdots X_n(p_n)}|w\rangle$, $p_1 + \cdots + p_n \in \mathbb{Z}$

For large twist $w \to \infty$ ($=$ **BMN limit**), there's an effective description:

can treat each $\boldsymbol{X_j(p_j)}$ as individual building block (unphysical state!)

Analytic continuation

$|\phi\rangle = \boldsymbol{X_1(p_1)} \cdots \boldsymbol{X_n(p_n)} |w\rangle$, $p_1 + \cdots + p_n \in \mathbb{Z}$

For large twist $w \to \infty$ ($=$ **BMN limit**), there's an effective description:

can treat each $\boldsymbol{X_j(p_j)}$ as individual building block (unphysical state!)

formally looks like (integrable) off-shell symmetry algebra from $\mathcal{N} = 4$ SYM [Beisert, '05]

Anomalous dimensions

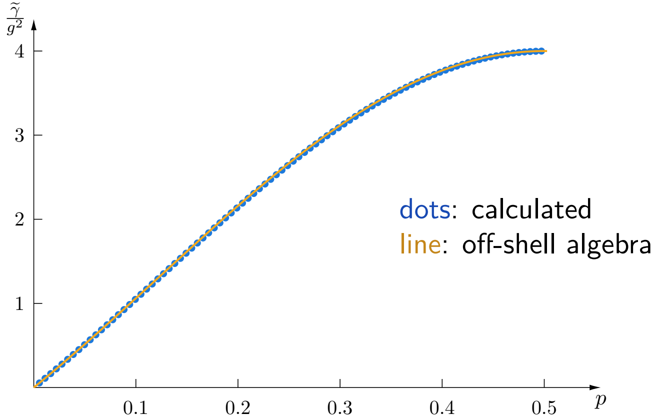
Calculate: unphysical state $X(p)\left|w\right\rangle$ has anomalous dimension

$$\epsilon(p) = g^2 \frac{\sin^2(\pi p)}{\pi p} + \mathcal{O}(g^4)$$

For $w \to \infty$, the anomalous dimension of $X_1(p_1) \cdots X_n(p_n)\left|w\right\rangle$ is sum of constituents

Anomalous dimensions

Anomalous dimension of physical state $|\phi\rangle = X(p)X(1-p)\,|w\rangle$



given by $\epsilon(p) + \epsilon(1-p)$, $\epsilon(p) = \frac{\sin^2(\pi p)}{\pi p}$ $\rightarrow$ independent excitations

Higher order anomalous dimensions

Assuming integrable structure persists at higher orders **fixes** anomalous dimension $\tilde{\mathcal{C}}$

Dispersion relation of single $\mathbb{T}^4$ magnon cf. [Hoare, Stepanchuk, Tseytlin, '13]:

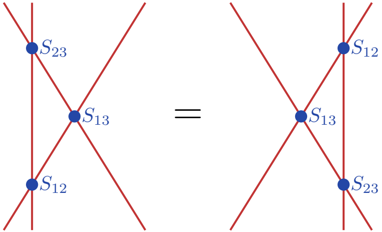
$$\tilde{\mathcal{C}}\, \alpha_{-p} |w\rangle = \left(\sqrt{p^2 + 4g^2 \, \sin^2 (\pi p)} - p \right) \alpha_{-p} |w\rangle$$

→ **masses** of string excitations in mixed flux background [Berenstein, Maldacena, Nastase, '02]

Integrable structure

The system has an S-matrix which satisfies the **Yang-Baxter equation**
$\rightarrow$ hallmark of **integrability**

Can be related to results from worldsheet integrability approach to AdS_3 [Lloyd, Ohlsson Sax, Sfondrini, Stefański, Jr., '14]



$\mathrm{AdS}_3 \times S^3$ directions

At large but finite w, can study following question:

$\mathrm{AdS}_3 \times S^3 \times \mathbb{T}^4$ has **8** directions (in light-cone gauge). $\mathrm{Sym}^N(\mathbb{T}^4)$ has **4**.

$\mathrm{AdS}_3 \times S^3$ directions

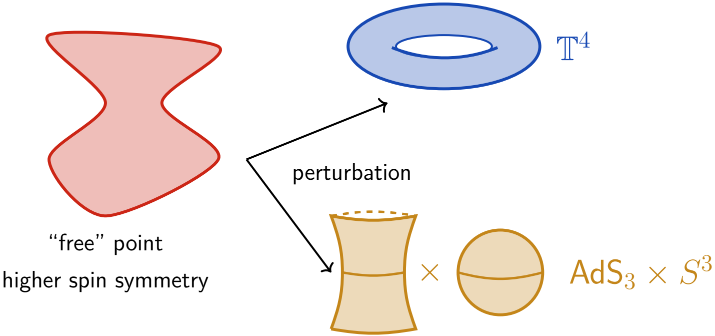
At large but finite w, can study following question:

$\mathrm{AdS}_3 \times S^3 \times \mathbb{T}^4$ has **8** directions (in light-cone gauge). $\mathrm{Sym}^N(\mathbb{T}^4)$ has **4**.

How are the $\mathrm{AdS}_3 \times S^3$ directions contained in the CFT?

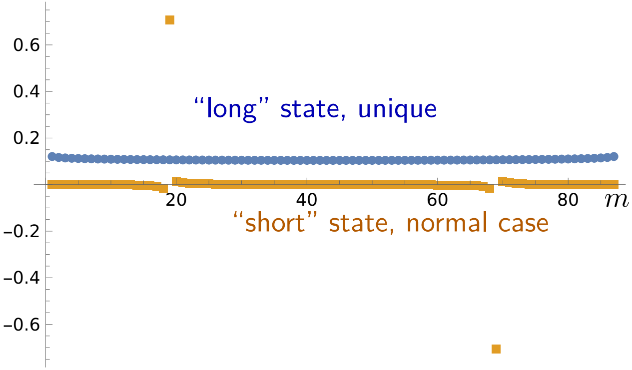
$\mathrm{AdS}_3 \times S^3$ directions

Perturbation breaks degeneracy, gives qualitatively different eigenstates.



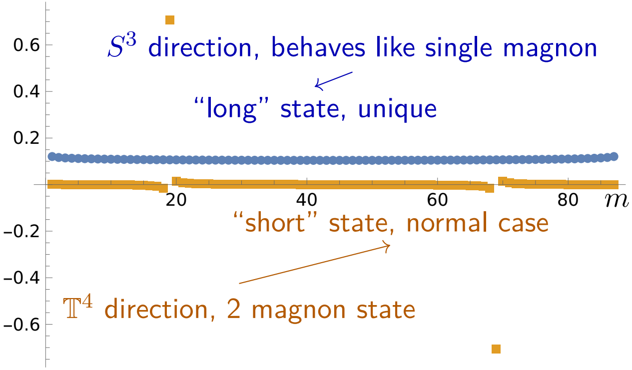
Eigenstates

eigenstate in basis $\psi^-_{\frac{1}{2}-\frac{m}{w}} \bar{\psi}^-_{-\frac{1}{2}+\frac{m+n}{w}}$



Eigenstates

eigenstate in basis $\psi^{-}_{\frac{1}{2}-\frac{m}{w}}\bar{\psi}^{-}_{-\frac{1}{2}+\frac{m+n}{w}}$



Danke!