The CFT Dual of a Tidal Force?

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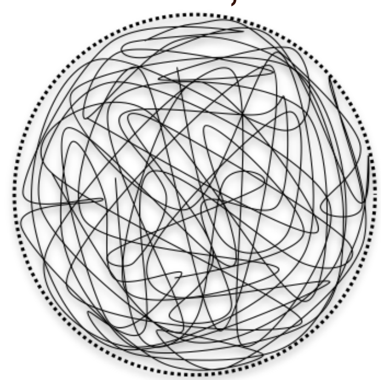


Motivation

- Microstate geometries program   Mathur, Lunin, Giusto, Russo, Bena Warner, Shigemori, Turton, Martinec…
    - smooth, horizonless geometries
    - same charges and mass of BH counterparts
    - horizon scale structure
    - composed objects in string theory

- A special class of three charge solutions called superstrata exhibit tidal forces   Yyukov, Walker, Warner 2017 Bena, Martinec, Walker, Warner 2018
- A string probe sent into a superstrata experiences tidal excitations along transverse directions   Martinec, Warner '20
- These geometries have an AdS_3 region
- There is a well defined map between these microstates and states within the D1D5 CFT   Bena et. al. '15, '18, Rawash, Turton '21

- We want to understand **tidal forces** from the perspective of the dual CFT

Motivation

- What is a diagnostic of this behavior?
- We'll need an interaction, a deformation of the CFT
- We need to generate excitations
- We'll consider two scenarios
  - 1) CFT dual of a probe moving in empty AdS (from 2 charge system)
  - 2) CFT dual of a probe moving in a superstrata geometry
- What are their differences?

Two Charge Solution

- Compactify IIB String Theory in 10D

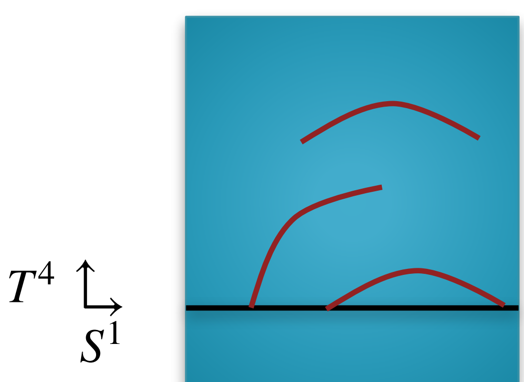
$$M_{4,1} \times S^1 \times T^4$$

- N_1 D1 branes wrap S^1
- N_5 D5 branes wrap $T^4 \times S^1$
- Share common direction S^1

Fully backreacted solution gives the super tube - (Lunin-Mathur - '01)
There is particular limit of the geometry which is

$$\underbrace{AdS_3}_{(t,r,y)} \times \underbrace{S^3}_{(\theta,\phi_1,\phi_2)} \times \underbrace{T^4}_{(x_6,x_7,x_8,x_9)}$$

$\uparrow$
S^1

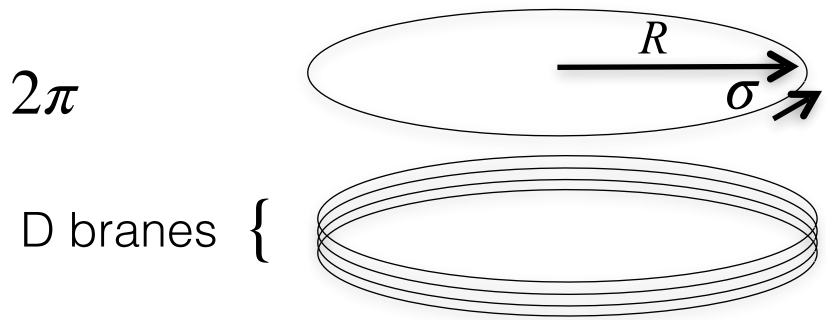


$\leftarrow$D1 brane where CFT lives

D1-D5 CFT

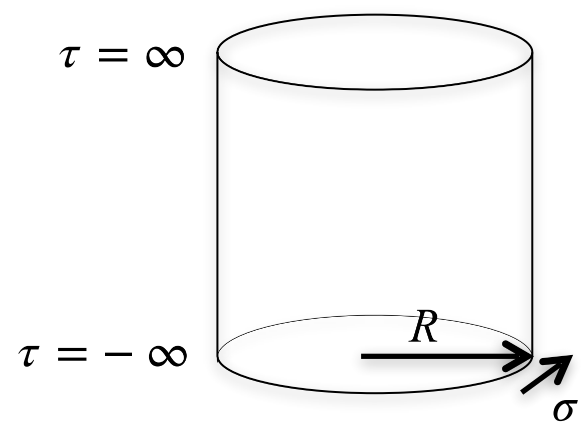
- Free CFT from a bound state of D1 and D5 branes wrapping a circle (called D strings) with $N = N_1 N_5$

$$\sigma = \frac{y}{R} \qquad 0 \le \sigma \le 2\pi$$



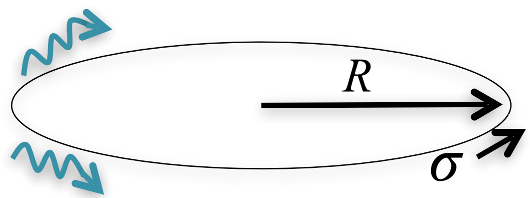
$$\tau = i\frac{t}{R} \qquad -\infty < \tau < \infty$$

$$w = \tau + i\sigma$$



D1-D5 CFT cont.

- Can have excitations of D-branes which correspond to ***open string*** excitations (4 bosons polarized along T^4, 4 fermions polarized along T^4 and S^3)



- Can have left movers and right movers

Interaction cont.

- Need to add an **interaction** to the theory to move closer to the supergravity description

$$S_0 \rightarrow S_0 + \lambda \int d^2 w D(w, \bar{w})$$

- Our interaction, $D(w, \bar{w})$ contains two main ingredients

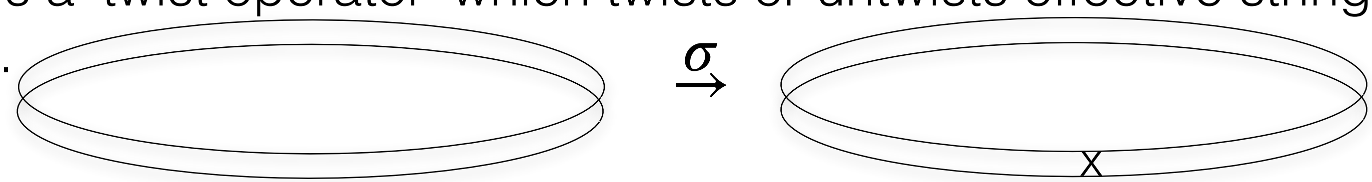
$$D(w, \bar{w}) = G\bar{G}\sigma(w, \bar{w})$$

- no bar – left-moving, bar - right moving
- G is a supersymmetric operator in the CFT

$\alpha : boson$ $\quad\quad$ $G : \alpha \rightarrow d$

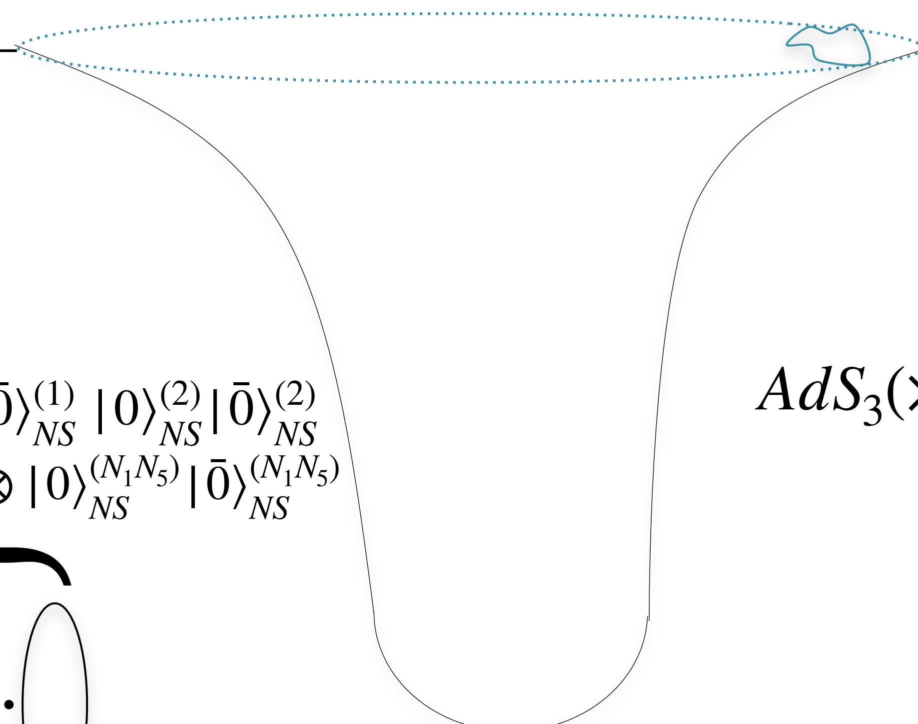
$d : fermion$ $\quad\quad$ $G : d \rightarrow \alpha$

- σ is a ‘twist operator’ which twists or untwists effective strings, i.e.

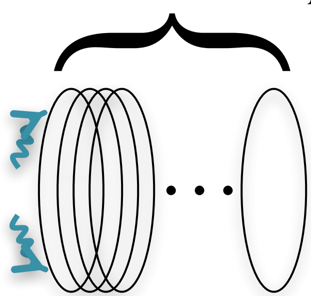


Consider a Graviton Probe Moving in Two Charge System

- left and right moving boson acting on a CFT Ground state composed of N singly wound strands in NS sector



$$\alpha^{(1)}_{-n}\bar{\alpha}^{(1)}_{-n}|0\rangle^{(1)}_{NS}|\bar{0}\rangle^{(1)}_{NS}\ |0\rangle^{(2)}_{NS}|\bar{0}\rangle^{(2)}_{NS} \otimes \ \dots \ \otimes |0\rangle^{(N_1N_5)}_{NS}|\bar{0}\rangle^{(N_1N_5)}_{NS}$$

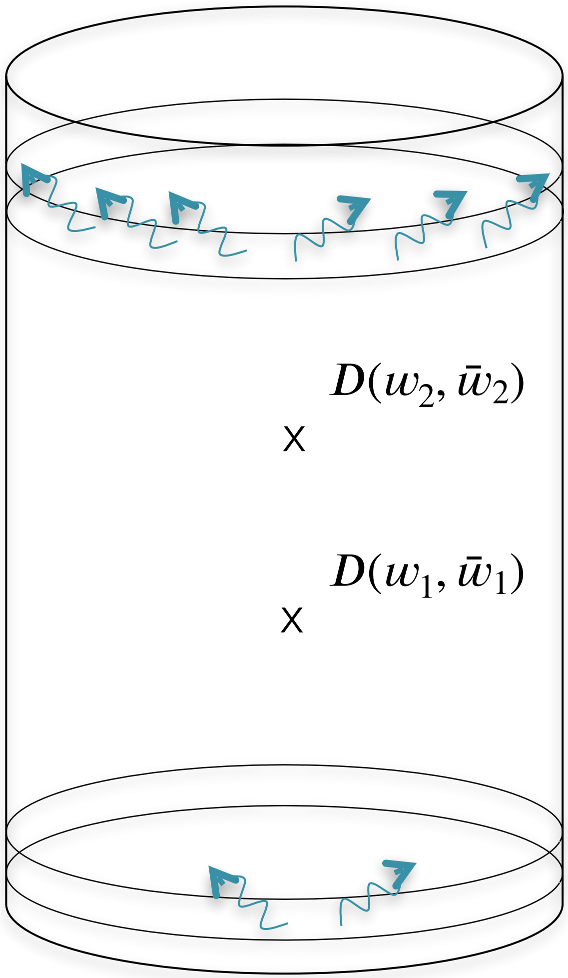


One excitation in initial state

- 1 Initial excitation and 3 final excitations

(I've suppressed polarization indices which are along T^4)

$$|\phi_1\rangle \sim \alpha_{-p}^{(1)}\alpha_{-q}^{(1)}\alpha_{-r}^{(1)}|0\rangle^{(1)}\bar{\alpha}_{-p}^{(1)}\bar{\alpha}_{-q}^{(1)}\bar{\alpha}_{-r}^{(1)}|\bar{0}\rangle^{(1)}|0\rangle^{(2)}|\bar{0}\rangle^{(2)} \otimes \ldots \otimes |0\rangle^{(N)}|\bar{0}\rangle^{(N)}$$



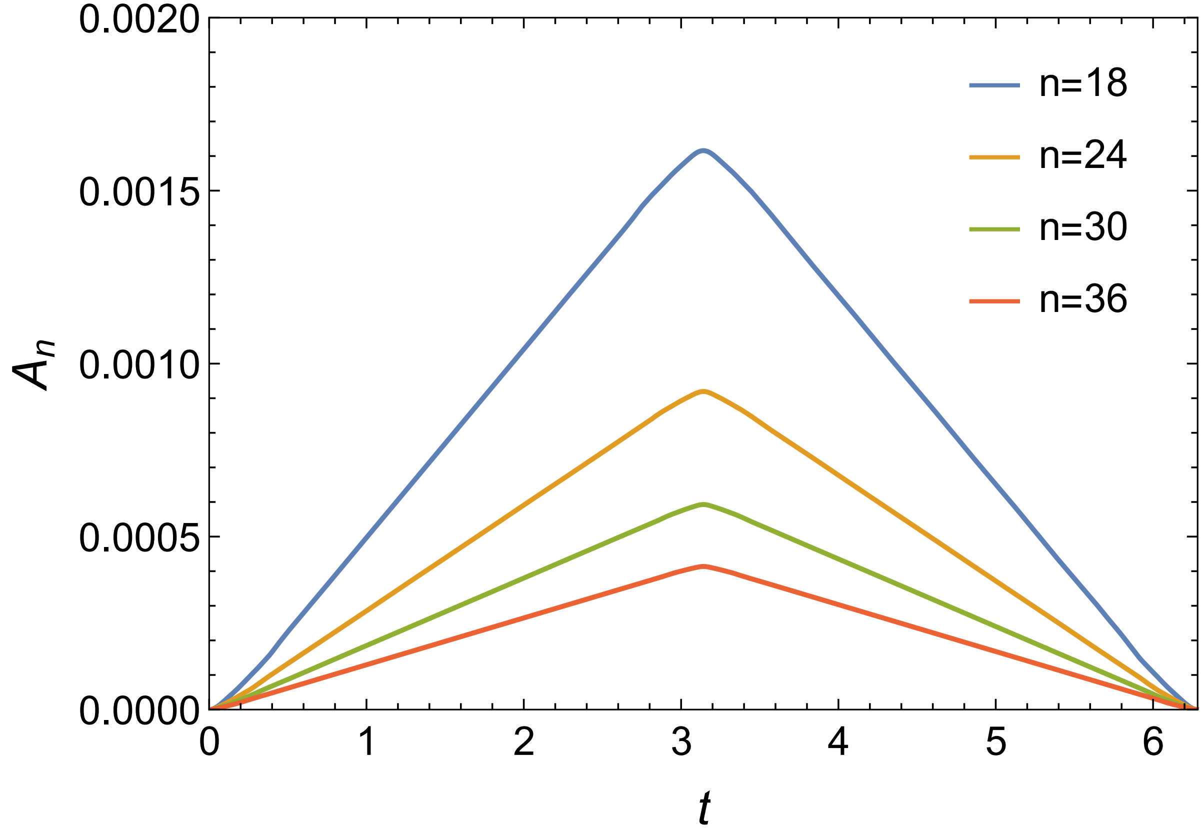
Pick the first two strings and twist them together and untwist them

Interested in computing **transition amplitude**, A_n^{11}

$N = N_1 N_5$

$$|\psi_1\rangle \sim \alpha_{-n}^{(1)}|0\rangle^{(1)}\bar{\alpha}_{-n}^{(1)}|\bar{0}\rangle^{(1)}|0\rangle^{(2)}|\bar{0}\rangle^{(2)} \otimes \ldots \otimes |0\rangle^{(N)}|\bar{0}\rangle^{(N)}$$

$$A_n^{11\to 11} \approx \lambda^2 \frac{c_1}{n^2}[t]_{(0,\pi),saw-like}$$

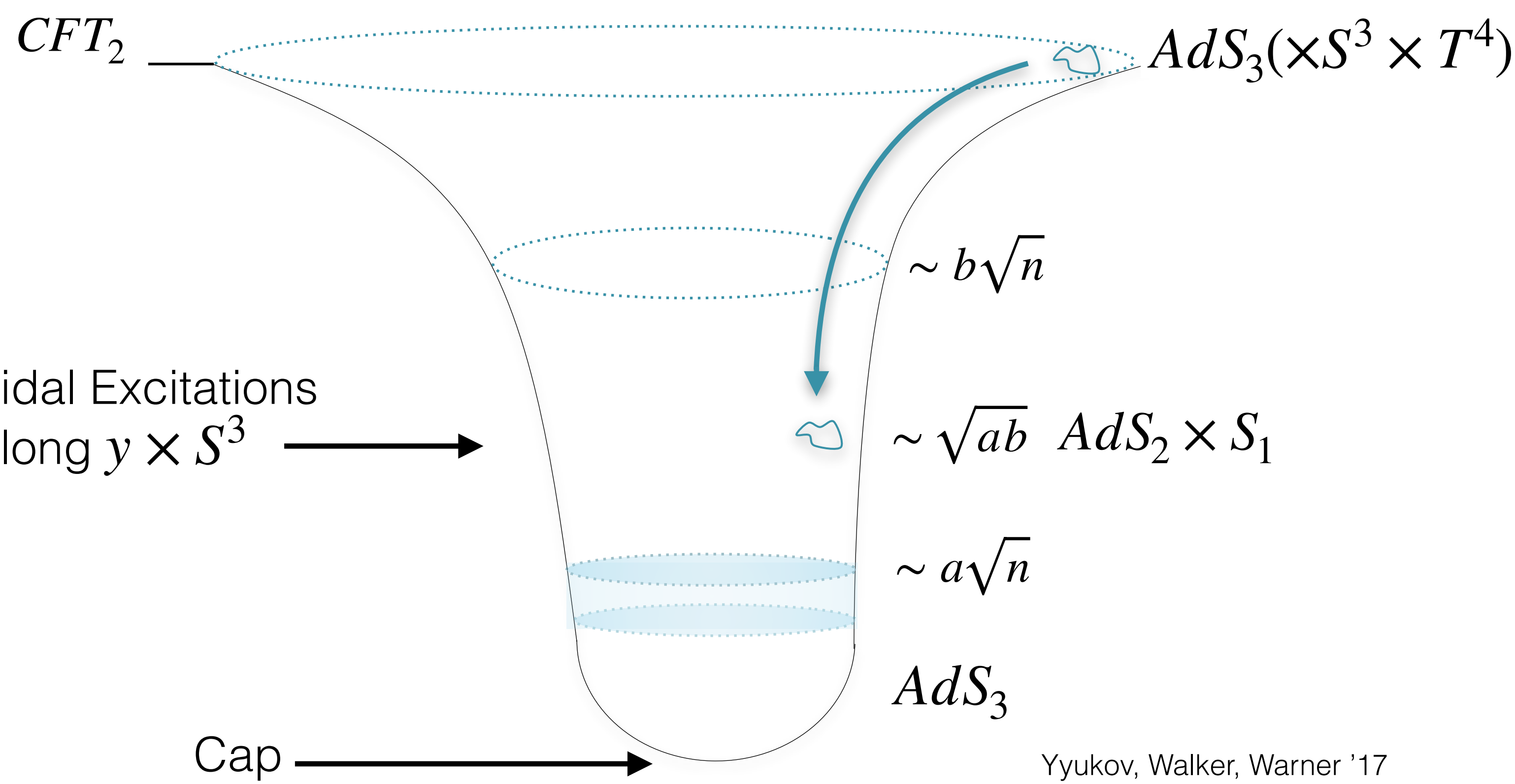


$t : [0,2\pi]$

Guo SH to appear

(1,0,n) Superstrata

- Probe moving in Superstrata - Fully backreacted, smooth, three charge solution with charges Q_1, Q_5, Q_p



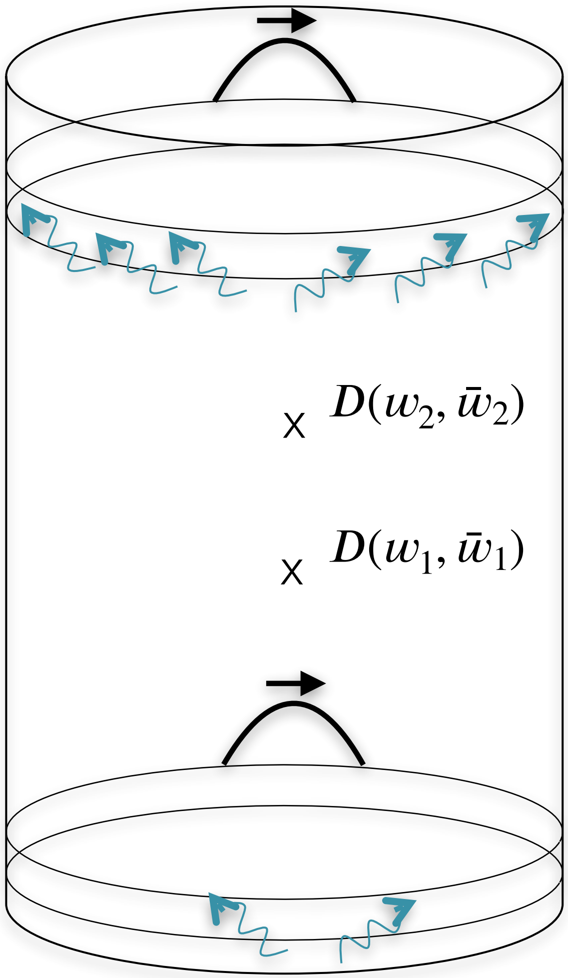
Yyukov, Walker, Warner '17
Bena, Martinec, Walker, Warner '18
Martinec, Warner '20

Special direction along $\theta = 0$

One excitation in initial state

- 1 Initial excitation → 3 Final excitations

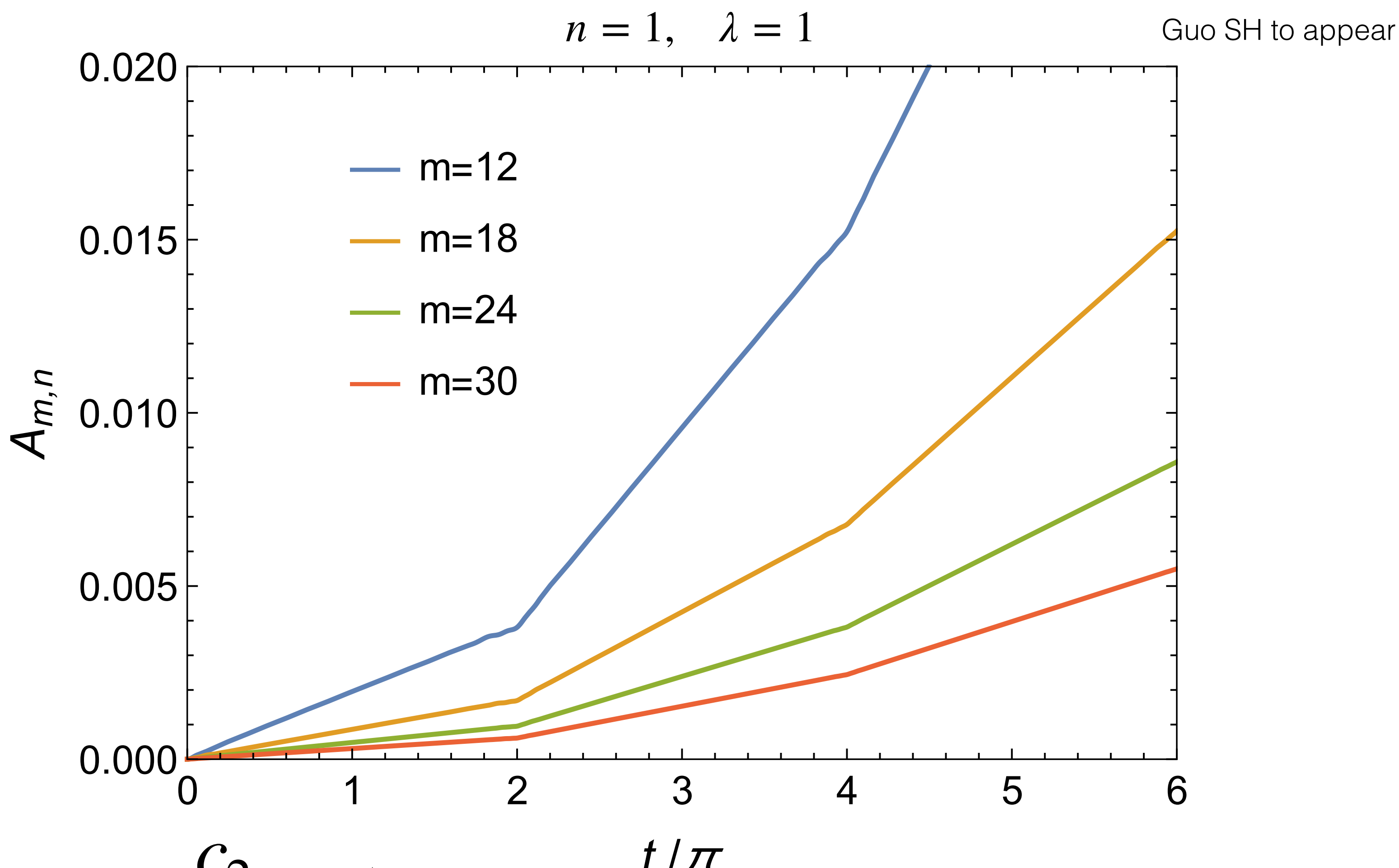
(I've suppressed polarization indices which are along T^4)



$$|\phi_1\rangle \sim \left(L_{-1} - J^3_{-1}\right)^n |00\rangle_1^{(1)}$$
$$\alpha_{-p} d^-_{-q} d^+_{-r} \bar{\alpha}_{-p} \bar{d}^+_{-q} \bar{d}^-_{-r} |++\rangle_1^{(1)}$$
$$\otimes_{N_{00}-1} \left(L_{-1} - J^3_{-1}\right)^n |00\rangle$$
$$\otimes_{N_{++}-1} |++\rangle_1$$

Again compute **transition amplitude**, $A_{m,n}$

$$|\psi_1\rangle \sim \left(L_{-1} - J^3_{-1}\right)^n |00\rangle_1 \alpha_{-m} \bar{\alpha}_{-m} |++\rangle_1$$
$$\otimes_{N_{00}-1} \left(L_{-1} - J^3_{-1}\right)^n |00\rangle$$
$$\otimes_{N_{++}-1} |++\rangle_1$$



$$-A_{m,n} = \frac{c_2}{m^2}\lambda^2\left(2\pi^2 t^2 + [-2\pi^2 t^2 + 4\pi^3 t]_{(0,\pi),saw-like}\right)$$

Comparing the two processes

Splitting in the vacuum

$$A_n^{11\to 11} \approx \lambda^2 \frac{c_1}{n^2}[t]_{(0,\pi),saw-like}$$

Splitting in presence of superstrata state

$$-A_{m,n} \approx \frac{c_2}{m^2}\lambda^2\left(2\pi^2 t^2 + [-2\pi^2 t^2 + 4\pi^3 t]_{(0,\pi),saw-like}\right)$$

- cancellation of t^2 term from $[0,\pi]$ gives a similar result as for the vacuum computation
  - linear t behavior
  - acts locally at first but then grows

Conclusion

- CFT dual of in-falling graviton corresponds to splitting of modes but no growth in the amplitude
- Probes moving in superstrata were shown to be tidally excited along S^3 and y directions
- Looked at CFT dual and found a growth in the splitting amplitude to produce fermions (carry S^3 charge)
- Suggestive of tidal excitations
- Suggests we should find similar behavior for excitations along T^4 in gravity picture. Indeed this was found. **Nejc** will discuss this in his talk
- Need to compute the corresponding amplitude in the CFT
- Investigate stringy modes in more detail
- Consider long winding sector

Thank you!