New Holographic CFTs: Finding the needle in the Haystack

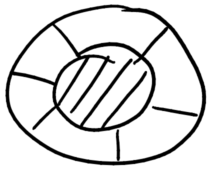
based on

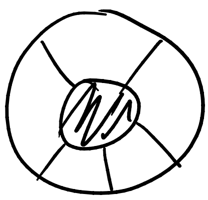
2002.07819 w/ N. Benjamin, A. Castro, S. Harrison, C. Keller

other papers w/ A. Castro, J. Gomes, C. Keller, B. Mühlmann

AdS/CFT:

Space of consistent, UV-complete ths of Q.G. in AdS_{d+1} $\Longleftrightarrow$ Space of CFT_d

 $\Longleftrightarrow$ $\langle O_1 \dots O_n \rangle$

We want  $\approx$ semi-classical GR

$\Rightarrow$ Most CFTs will not be of this type

2 Step process:
① Find conditions that guarantee it
② Build (all) CFTs that satisfy them

Conditions

- Large N: $\dfrac{\ell_{AdS}}{\ell_P} \gg 1$
- Large Gap $\Delta_{s>2} \geq \Delta_{gap} \gg 1$ " $\dfrac{\ell_{AdS}}{\ell_s}$ " [HPPS]
- Sparse Spectrum $\rho(\Delta) \lesssim e^{2\pi\Delta}$ [HKS]
- Very Sparse Spectrum

$$\rho(\Delta) \sim e^{\# \Delta^{\alpha}} \qquad \alpha < 1$$

$$\alpha = \frac{D-1}{D} \qquad F_{bulk} \sim T^{D}$$

LQFT

Wish to consider:

Symmetric Orbifolds $\quad \mathcal{C}^{\otimes N} / S_N$

- Large N ✓
- $\rho_L(\Delta) = e^{2\pi\Delta}$ ✓

- Large Gap ✗
- $\rho_L(\Delta) \sim e^{\Delta^\alpha}$ ✗

What about D1-D5 CFT?

$$S_{orb} \longrightarrow S_{orb} + \lambda \int d^2z \, \mathcal{O}(z,\bar{z})$$

Exactly Marginal Op.
$(h,\bar{h}) = (1,1)$ protected (by susy)

$\lambda = 0$	$\lambda \gg 1$
$\rho_L(\Delta) = e^{2\pi\Delta}$	$\rho_L(\Delta) \sim e^{\Delta^{5/6}}$
$\Delta_{gap} = 1$	$\Delta_{gap} \sim \lambda^{\#} \gg 1$

$AdS_3 \times S^3$

We had $\mathcal{C} = T^4$ or $K3$

$$\boxed{\text{Can we find other examples??}}$$

Focus on SCFTs with $\mathcal{N} = (2,2)$

Holographic Conditions (necessary)

2 Diagnostics:

- 1) $\exists$ Marginal operator
- 2) Growth of the (BPS) spectrum

$$\rho_L(\Delta) \sim e^{\Delta^\alpha} \, , \quad \alpha < 1$$

Marginal Operators

$$\delta S = N^{1-K/2} \lambda \int d^2 z \; \mathcal{O}^{K}(z,\bar{z})$$

$\Rightarrow$ We want:

- $K = 1$
- $\mathcal{O}$: $(h,\bar{h}) = (1,1)$ protected $\Rightarrow \left(G_{-1/2} \bar{G}_{-1/2} |h=1/2, q=1\rangle \right)$
- $\mathcal{O}$ to be in twisted sector

$$h^{L}_{G.S.} = \frac{c}{12}(L-1)$$

$h = 1/2, \; L = 2 \Rightarrow \boxed{c \lesssim 6}$

$\Rightarrow$ Already strong constraint!

The spectrum

Study Elliptic Genus:

$$\chi(\tau, z) := \mathrm{Tr}_{RR} (-1)^{F+\bar{F}} q^{L_0 - \frac{c}{24}} y^{J_0} \bar{q}^{\bar{L}_0 - \frac{\bar{c}}{24}}$$

$\Rightarrow$ Protected on the conf. manifold

$\Rightarrow$ Related to a weak Jacobi form

$\Rightarrow$ finite n° of possibilities !!!

Papers in Oct: complete classification

$$g_L^{\chi}(\Delta) : \begin{cases} e^{\#\Delta} & \times \\ e^{\Delta^{1/2}} & \text{promising} \end{cases}$$

Simple criterion : For Ex : $\boxed{c \lesssim 6}$

$\mathcal{N}=2$ Minimal Models

$c \leqslant 6$

$\Downarrow$

$\boxed{1 \leqslant c \leqslant 3}$ $\Rightarrow$ complete classification : $\mathcal{N}=2$ Min. Models

$$c = \frac{3k}{k+2}, \quad k = 1, \dots$$

A series
D series
E6, E7, E8

$\searrow$ $3 \leqslant c \leqslant 6$

Main Result

All min models have **both** $\begin{cases} \text{marg op. (s.t. twisted)} \\ \text{slow growing E. 6.} \end{cases}$

$\Rightarrow$ Evidence for infinite new landscape of holographic CFTs!

$3 \leqslant c \leqslant 6$ Either: $\begin{cases} \text{satisfy both} \\ \text{fail both} \end{cases}$ (1 case of fast growth with marg. op.)

Where to go?

- Find SUGRA dual or brane construction
- Prove they have a large gap
- AdS phenomenology

AdS phenomenology

The conformal manifold is very rich

$\exists$ exactly marginal multi-trace operators

$$\delta S = \frac{\lambda_3}{\sqrt{N}} \int d^2z \, :O^3:$$

$$\langle O\,O\,O \rangle_{\lambda_3} = C_{OOO} + \frac{\lambda_3}{\sqrt{N}} \overbrace{\int d^2z \, \langle O\,O\,O \; O^3 \rangle}^{\langle OO\rangle\langle OO\rangle\langle OO\rangle \sim O(1)}$$

tune OPE coeffs!

Beyond large N factorization

$$\delta S = \lambda_3 \int d^2z \, :O^3:$$

$$\delta S = \frac{\lambda_3}{\cancel{\sqrt{N}}} \int d^2 z \; :\mathcal{O}^3:$$

$$\langle \mathcal{O}\mathcal{O}\mathcal{O} \rangle_{\lambda_3} = \underbrace{C_{\mathcal{O}\mathcal{O}\mathcal{O}}}_{\sim \mathcal{O}\left(\frac{1}{\sqrt{N}}\right)} + \underbrace{\lambda_3}_{\sim \mathcal{O}(1)}$$

Strongly coupled QFT in AdS coupled to gravity!!