Higher Spin Holography in de Sitter Space

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Based on: 1108.5735 with D. Anninos and A. Strominger

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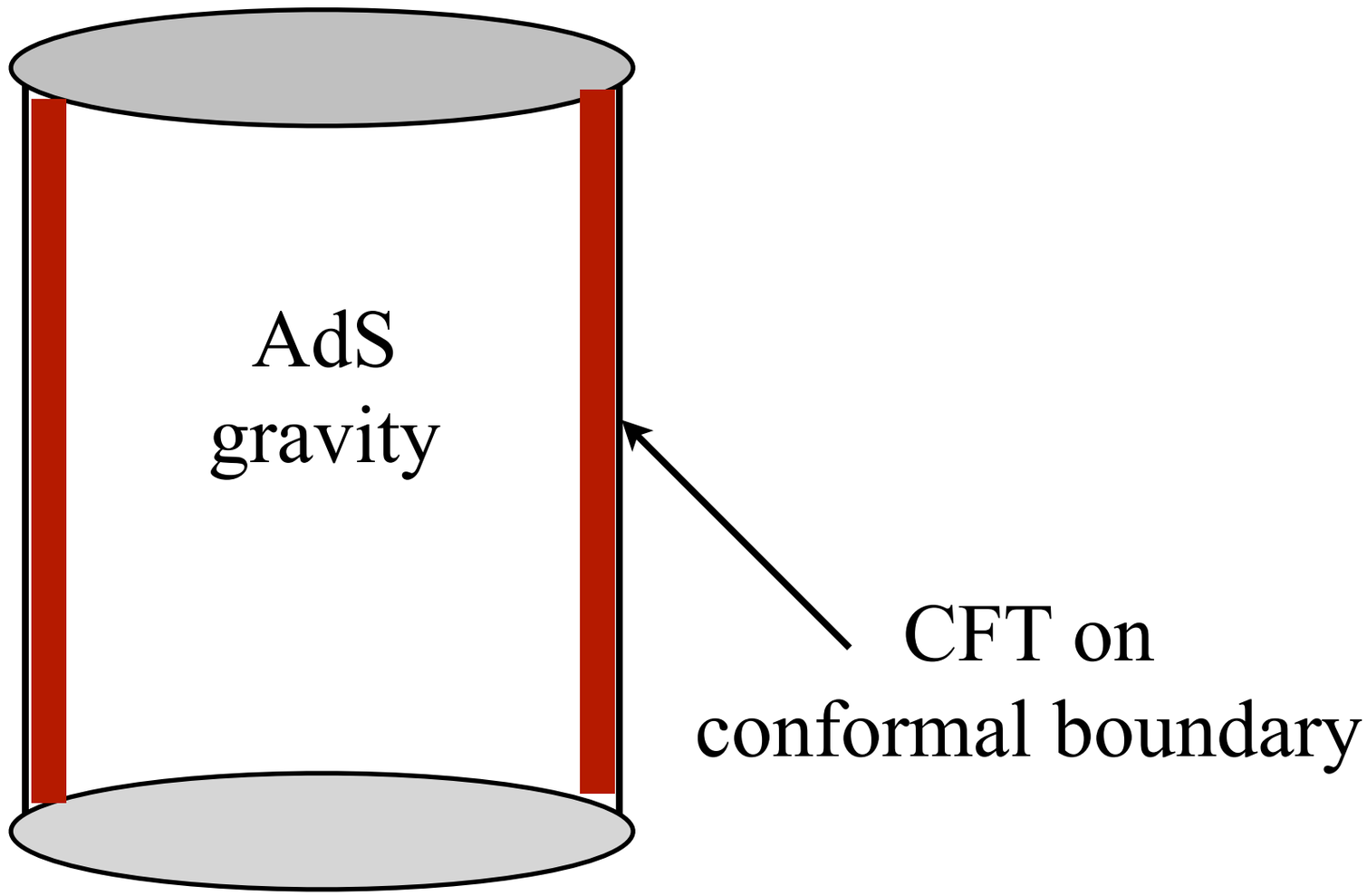
Introduction

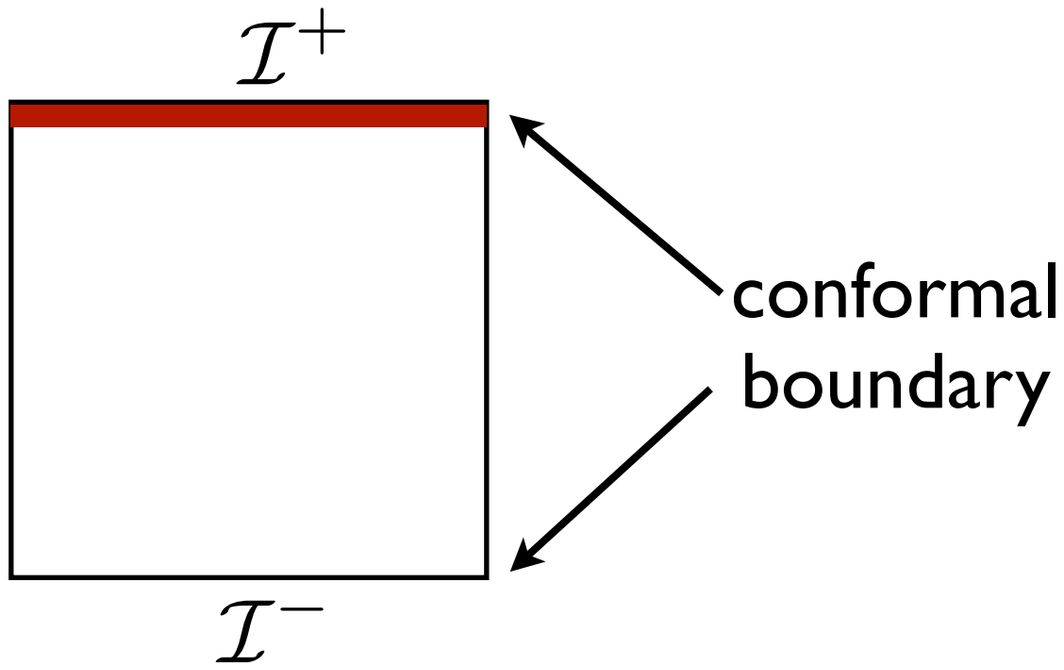
The AdS/CFT correspondence provides a non-perturbative definition of quantum gravity with negative cosmological constant.



But we live in (asymptotically) de Sitter space, in the past and future.

Introduction

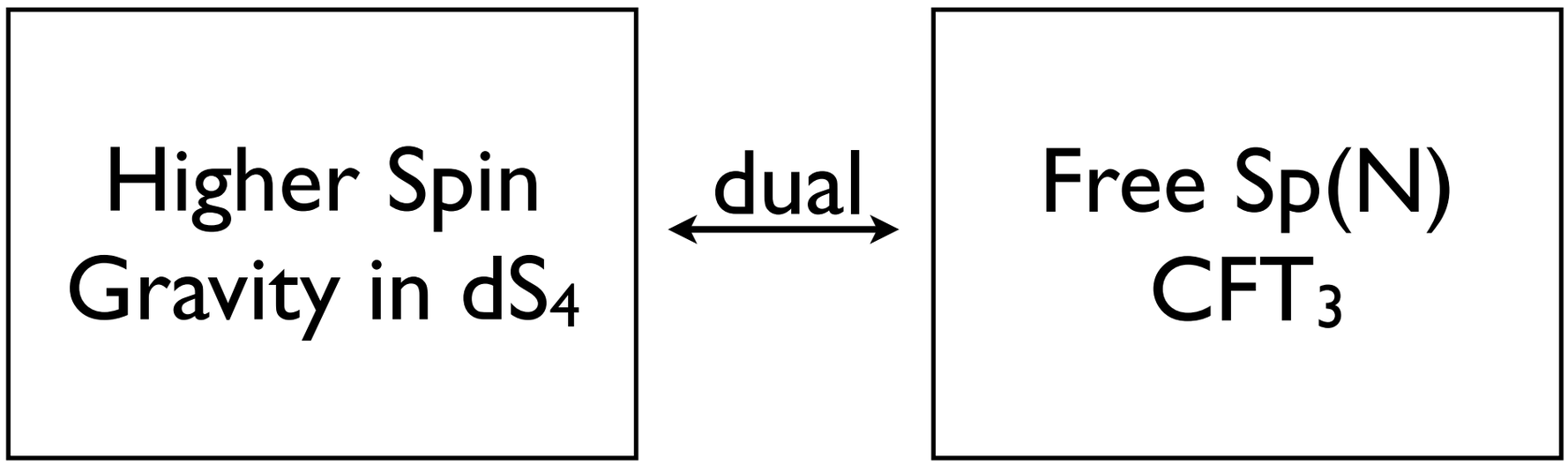
The dS/CFT correspondence, if it exists, is very different from AdS/CFT. Time is emergent:



A general dS/CFT dictionary has been proposed, but an explicit example was lacking.

Witten '01; Strominger '01; Maldacena '02.

Introduction



$$\Lambda \sim 1/N$$

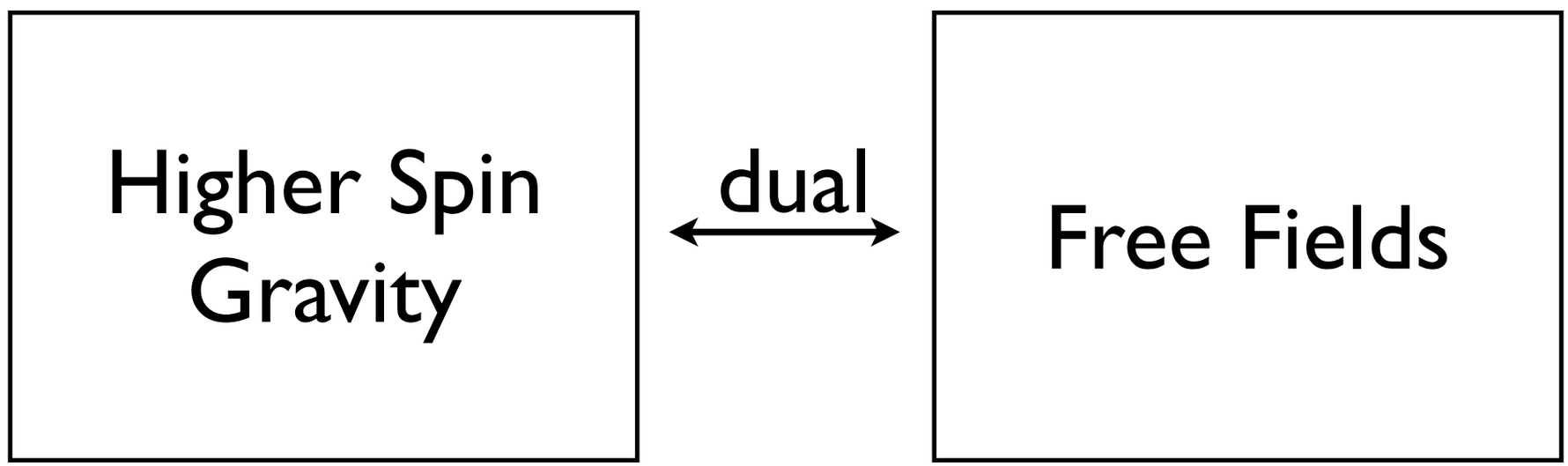
Some Background:
Negative Cosmological Constant

Higher Spin Dualities

4d higher spin gravity has an infinite number of massless gauge fields,

$$A_{\mu_1 \cdots \mu_s} \qquad s = 0, 1, 2, 3, 4, \cdots ,$$ Vasiliev, 1990

These gauge fields are dual to the infinite conserved currents of a free field theory.



$$A_{\mu_1 \cdots \mu_s} \quad \leftrightarrow \quad \phi \partial_{(\mu_1} \cdots \partial_{\mu_s)} \phi$$

O(N) Duality

An AdS/CFT Example

- Bulk: Vasiliev's Higher Spin Gravity
- CFT: N Free Fields -- the singlet sector of the free O(N) model

$$\phi^a \partial \cdots \partial \phi^a$$

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Fronsdal '79
Witten
Sundborg
Mikhailov
Sezgin & Sundell
Klebanov & Polyakov
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Evidence

- Matching spectrum
- Matching 3-point correlation functions — Petkou; Giombi and Yin
- Assuming consistency: all n-point functions match — Maldacena, Zhiboedov

Proposal for $\Lambda > 0$

Note: supersymmetry was not required in AdS.

dS/CFT

The Bulk

- Vasiliev's higher spin gravity in dS_4
- Massless gauge fields of all even spins

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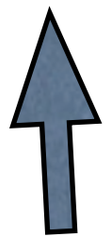
Guessing the Boundary CFT

- Recall cosmo. constant $\Lambda \sim 1/N$
- Looking for the "O(-N)" model



this is a statement about correlators

The Sp(N) Model

N free anticommuting scalars ("ghosts")

$$S_{cft} = \frac{1}{2} \int d^3x \; \Omega_{ab} \; \partial\chi^a \cdot \partial\chi^b$$

$\Omega \equiv$ antisym. symplectic form

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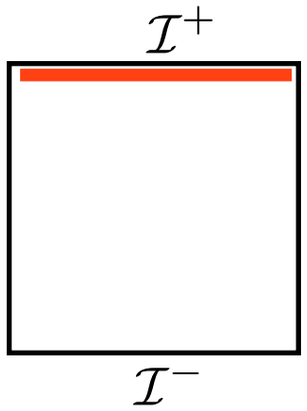
- In Lorentzian signature, this would be non-unitary.
- Our CFT is Euclidean; unitarity is not an issue.
- Nonetheless bulk unitarity should be encoded somehow in the CFT.



The Claim

Vasiliev gravity in dS_4 = Sp(N) CFT

Evidence

- Spectrum
- 3-point correlators

Correlators

Matching Correlators

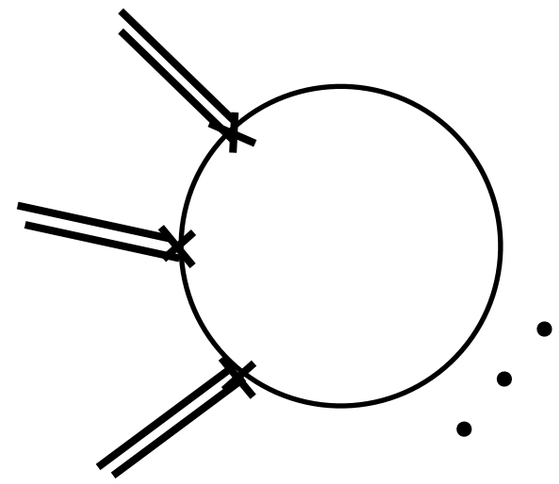
Strategy

- Relate bulk and boundary correlators to their AdS counterparts, by N --> -N
- Then evidence for O(N) duality carries over to this case.

This is an easy way to compute, but is just for convenience. All quantities are defined intrinsically in dS and the Sp(N) model, *not* by analytic continuation.

CFT Correlators

$$\left\langle J^{(s_1)} J^{(s_2)} \dots J^{(s_n)} \right\rangle_{cft} =$$



N-dependence is just an overall factor.

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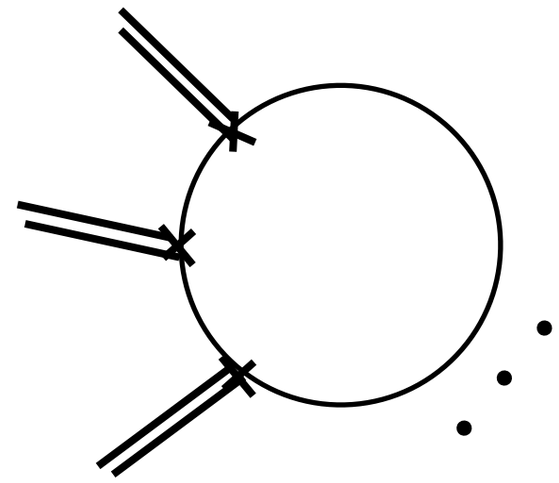

N-dependence is just an overall factor.

Fermi statistics:

$$\langle J \cdots J \rangle_{Sp(N)} = -\langle J \cdots J \rangle_{O(N)}$$

So “Sp(N) = O(-N)”

Bulk Correlators

What should we compute? ("The dictionary")

AdS/CFT

$$Z_{cft}[X_0] = Z_{bulk}[X_0] = \int DX e^{-S_{bulk}[X]}$$

cft correlators $\sim$ bulk vev

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Maldacena
cf: Harlow and Stanford

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Bulk Correlators

How to compute it?

$$\Psi_{bulk}[X_0] \sim e^{iS_{bulk}[X]}$$

- This could be computed by solving the Vasiliev equations perturbatively in de Sitter.

- However it has already been done in AdS, Giombi, Yin
  - so easier to compute by analytic continuation
  - Continuing Giombi-Yin to positive CC, we find

$$\langle J \cdots J \rangle_{dS} = -\langle J \cdots J \rangle_{EAdS}$$

Correlators Match.

Therefore, borrowing AdS 3-pt functions from Giombi and Yin,

$$\langle JJJ \rangle_{dS} = \langle JJJ \rangle_{Sp(N)CFT}$$

The results of Maldacena and Zhiboedov implies that all n-point correlators match.

Final Comments

Entropy?

3d CFTs have a quantity called “F”, the partition function on a 3-sphere, which is always decreases under RG flow.

Myers et al; Jafferis; Jafferis et al; Casini & Huerta

The dS/CFT dictionary $Z_{cft} = \Psi_{bulk}$ relates this quantity to cosmological entropy:

$$\text{Entropy} = -2F$$

This relates the second law of thermodynamics to recent progress in 3d CFT.

second law $\quad\leftrightarrow\quad$ F-theorem.

Problem: Compute the on-shell action of higher spin gravity on a 4-sphere.

Comments

1. Usually, analytic continuation of correlators does not give a reasonable theory; the O(N) model and Vasiliev gravity are very special in this regard.

2. Non-perturbatively, Sp(N) model is not “O(-N)”

3. An interacting critical Sp(N) duality also exists

in AdS: Klebanov & Polyakov

4. Time evolution = RG Flow; ex: Mass deformation

Conclusion

Higher spin gravity is dual to solvable (free in 3d) CFTs, and may allow a UV-complete holographic duality in de Sitter.

Things you might hope to compute:

- RG flows corresponding to universe production
- non-perturbative wavefunction of the universe
- de Sitter entropy
- static patch observables

Ultimately, seeking general rules for de Sitter holography.