Higher spin AdS_3 holography and superstring theory

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Motivation

- Gauge theory of higher spin fields
  - Natural extension of electromagnetism (s=1) and gravity (s=2)
  - A toy model for the tensionless limit of superstring theory
  - Vasiliev theory is famous as a non-trivial theory
- Applications to AdS/CFT
  - More tractable AdS/CFT correspondence can be constructed than using superstring theory
  - Examples
    - 4d Vasiliev theory ⇔ 3d O(N) vector model [Klebanov-Polyakov '02]
    - 3d Vasiliev theory ⇔ 2d large N minimal model [Gaberdiel-Gopakumar '10]

HS ⇔ String

- Past trials
  - HS from String
    - Vasiliev theory as a truncation of the tensionless limit of string theory?
    - Superstring theory includes a lot of massive HS states
  - Sting from HS
    - String theory as a broken phase of HS theory? [Gross '88]
    - HS symmetry is restored at the high energy limit of string theory
- Developments via AdS/CFT
  - ABJ triality [Chang-Minwalla-Sharma-Yin '12]
    - 4d extended Vasiliev ⇔ 3d ABJ theory ⇔ Superstrings on $AdS_4 \times CP^3$
  - AdS_3 version [Gaberdiel-Gopakumar, CHR '13-'14]
    - 3d extended Vasiliev ⇔ 2d coset model ⇔ Superstrings on $AdS_3 \times M_7$

Plan of the talk

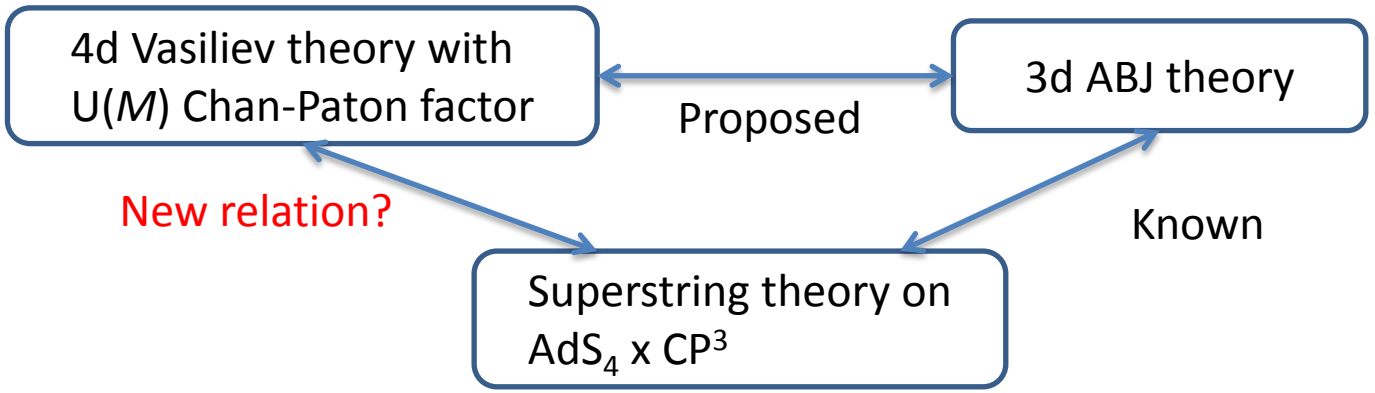
- ✓ Introduction
- ABJ triality
- AdS_3 version
- Conclusion

ABJ triality

AdS_4/CFT_3

- Original HS/CFT duality
  - 3d U(N) vector model ⇔ 4d Vasiliev theory
- ABJ triality
  - CFT side: Coupled with $U(N)_k$ x $U(M)_{-k}$ Chern-Simons gauge field (ABJ theory)
  - HS side: 4d extended Vasiliev theory with U(M) Chan-Paton factor
  - String side: Also dual to superstrings on AdS_4 x CP^3

    [Chang-Minwalla-Sharma-Yin '12]



ABJ triality

- Without CP factor
  - U(*N*) vector model includes free fields $\phi_i \ (i = 1, 2, \ldots, N)$
  - U(*N*) invariant currents from CFT ⇔ HS gauge fields

$$J_{\mu_1 \ldots \mu_s} = \bar{\phi}_i \partial_{(\mu_1} \cdots \partial_{\mu_s)} \phi^i \qquad\qquad \varphi_{\mu_1 \ldots \mu_s}$$

- With U(*M*) CP factor

$(\alpha = 1, 2, \ldots, M)$

  - ABJ theory includes (*N* x *M*) matrix valued bi-fundamentals A_i^α, B_β^j
  - U(*N*) invariant currents from CFT ⇔ Matrix valued HS gauge fields

$$[J_{\mu_1 \ldots \mu_s}]^\alpha_\beta = A_i^\alpha \partial_{(\mu_1} \cdots \partial_{\mu_s)} B^i_\beta \qquad\qquad [\varphi_{\mu_1 \ldots \mu_s}]^\alpha_\beta$$

- Relation to superstring theory
  - Operator dual to string: $\mathrm{tr}[ABAB \cdots AB]$
  - Need CP factor & U(*M*) invariance

AdS_3 version

AdS_3/CFT_2

[CHR '13] (c.f. [Gaberdiel-Gopakumar '13] for M=2)

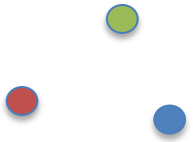
- Gaberdiel-Gopakumar proposal '10
  - 3d Vasiliev theory ⇔ 2d large N minimal model
- Extension
  - HS side: 3d Vasiliev theory with U(M) CP factor
  - CFT side: 2d Grassmannian-like model at 't Hooft limit

$$\frac{\mathrm{su}(N+M)_k \oplus \mathrm{so}(2NM)_1}{\mathrm{su}(N)_{k+M} \oplus \mathrm{u}(1)} \qquad \left(N, k \to \infty,\ M, \lambda = \frac{N}{N+k+M} : \text{finite}\right)$$

- Evidence
  - M=1 case reduces to the known duality without CP factor
  - The theory consists of bi-fundamentals at the free limit (k>>N)
  - Match of 1-loop partition functions [CHR, Candu-Vollenweider '13]

Dual superstring theories

- With Wolf space model (M=2) [Gaberdiel-Gopakumar '13]
  - GOOD: Large N=4 SUSY (or small N=4 for k>>N)
    - Dual superstring theory is known
    - Comparison with known results for small N=4 [Gaberdiel-Gopakumar '14]
  - BAD: Only consider M=2
    - Corresponds to subsector with String Bit = Higher Spin Particle
- With Grassmannian model [CHR '13]
  - GOOD: Possible to deal with generic M>2
    - Supposed to be dual to the whole string theory
  - BAD: N=2 SUSY is not enough to determine dual superstring theory
    - SUSY is enhanced to N=3 at k=N+M [CHR '14]



N=3 holography

[CHR '14, in progress] (c.f. [Beccaria-Candu-Gaberdiel-Groher '13] for *n*=0)

- Triality with *N*=3 SUSY
  - CFT side: 2d *N*=3 critical level model

$$\frac{\mathrm{su}(N+M)_{N+M} \oplus \mathrm{so}(2NM)_1}{\mathrm{su}(N)_{N+2M} \oplus \mathrm{su}(M)_{M+2N} \oplus \mathrm{u}(1)} \quad (\oplus \mathrm{su}(M)_{M+2N}) \,, \qquad M = 2^{n-1}$$

  - HS side: 3d Vasiliev theory with *N*=2n+1 extended SUSY
  - String side: AdS_3 x SU(3)/U(1) (or SO(5)/SO(3)) [Argurio-Giveon-Shomer '00]
- Evidence
  - HS/CFT duality: well understood
    - Match of one-loop partition functions and symmetry at low spins
  - String/CFT duality: less understood
    - *N*=3 SUSY, BPS spectrum, marginal deformations

Conclusion

Conclusion

- AdS_3 version of ABJ triality
  - 3d Vasiliev theory ⇔ 2d coset model ⇔ Superstrings on $AdS_3 \times M_7$
    - HS fields with U(*M*) CP factor + *N*=3 extended SUSY
    - HS/CFT duality has strong supports
- Future directions
  - More study on the String/CFT duality
    - Marginal deformations should break HS symmetry
    - What does *M* means in dual string theory?
    - Construct corresponding brane configuration
  - More study on the String/HS duality
    - Higgs mechanism of higher spin gauge theory