Self-dual holography:
AdS/CFT and celestial, with an example of SDYM

Simons Collaboration on Celestial Holography Satellite Meeting

Evgeny Skvortsov, UMONS

April 14, 2026

European Research Council

Established by the European Commission

Université de Mons

FREEDOM TO RESEARCH

Main Messages/Plan

- Self-dual theories are useful models of their parent completions with many remarkable features
- There are lots of SD-theories, if higher spins are allowed
- Since SD-theories are UV-finite, one can look for their place in AdS/CFT and celestial holography
- The maximal SD-theory, chiral higher-spin gravity, has the spectrum big enough to be dual to something less exotic, while SDYM and SDGR should be dual to some universal subsectors of correlators
- We work out the (SD)YM case explicitly: Fefferman-Graham, AdS/CFT dictionary, propagators, amplitudes/correlators and discuss Dirichlet/Neumann/mixed/self-dual holography

Why self-dual?

What is self-dual? How much self-dual?

Why we love self-dual theories?

- simpler than the parent theories, but nontrivial (get self-dual today and pay for the rest later)
- twistors, integrability, instantons (Penrose; Wald; ADHM; ...)
- **SD theories are consistent truncations**, so anything we can compute will be a legitimate observable in the full theory; **Unitary physics from nonunitary theories!**
- **actions are “unreal” in Minkowski space**

Amplitudes, strings, twistors, ... encourage to go outside real/Minkowski

In higher spins: little explored (Adamo, Hähnel, McLoughlin, E.S., Ponomarev, Tran, Krasnov, Herfray, Mason, Sharma), can be the only reasonably local theories with massless higher spins

Self-dual Yang-Mills (SDYM)

It is easy to get SDYM as "truncation" of YM ($\boldsymbol{A}_\mu \to \boldsymbol{\Phi}^{\pm}$)

$$\mathcal{L}_{\mathsf{YM}} = \mathbf{tr}\, \boldsymbol{F}_{\mu\nu} \boldsymbol{F}^{\mu\nu}$$

$$\wr\wr$$

$$\mathcal{L}_{\mathsf{YM}/\mathsf{SDYM}} = \boldsymbol{\Phi}^{-} \Box \boldsymbol{\Phi}^{+} + \boldsymbol{V}^{++-} + \boldsymbol{V}^{--+} + \boldsymbol{V}^{++--}$$

Self-dual Yang-Mills (SDYM)

It is easy to get SDYM as "truncation" of YM ($\boldsymbol{A_\mu} \rightarrow \boldsymbol{\Phi^\pm}$)

$$\mathcal{L}_{\text{YM}} = \mathbf{tr}\, \boldsymbol{F_{\mu\nu}F^{\mu\nu}}$$

$$\wr\wr$$

$$\mathcal{L}_{\text{YM/SDYM}} = \boldsymbol{\Phi^- \Box \Phi^+} + \boldsymbol{V^{++-}} + \boldsymbol{V^{--+}} + \boldsymbol{V^{++--}}$$

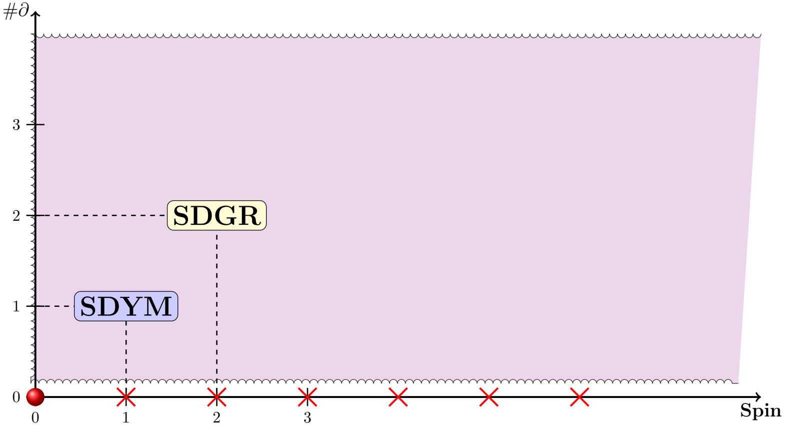
SDYM can also be described covariantly with the help of

$$F \wedge F = F^2_{AB} - F^2_{A'B'} \qquad\qquad F^2_{\mu\nu} = F^2_{AB} + F^2_{A'B'}$$

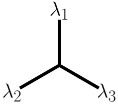
where F_{AB}, $F_{A'B'}$ are the (anti)self-dual components in the $sl(2,\mathbb{C})$-language. Next, a couple of tricks due to (Chalmers, Siegel)

$$S_{YM} = \int F^2_{\mu\nu} \sim \int F^2_{AB} \sim \int \boldsymbol{\Psi^{AB} F_{AB}} - \boldsymbol{\frac{\epsilon}{2}\Psi^2_{AB}}\,,$$

What else is self-dual?

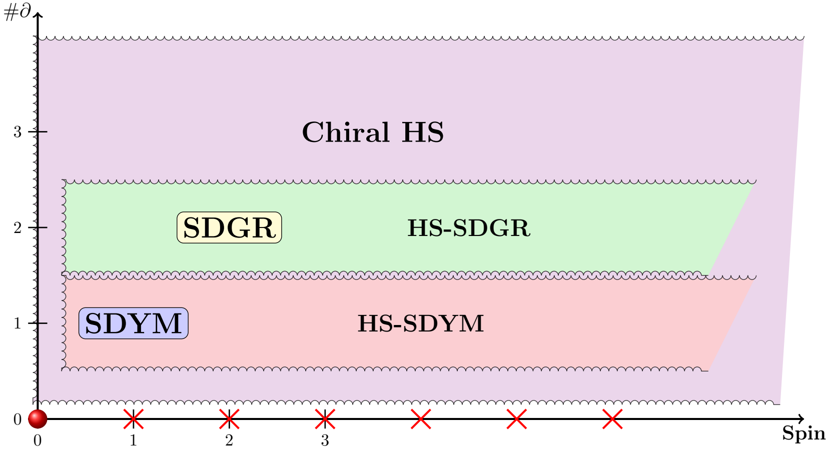


$C_{\lambda_1,\lambda_2,\lambda_3}[12]^{\lambda_1+\lambda_2-\lambda_3}[23]^{\lambda_2+\lambda_3-\lambda_1}[31]^{\lambda_3+\lambda_1-\lambda_2}$ $\sim$



(Bengtsson[2], Brink, Linden; Benincasa, Cachazo)

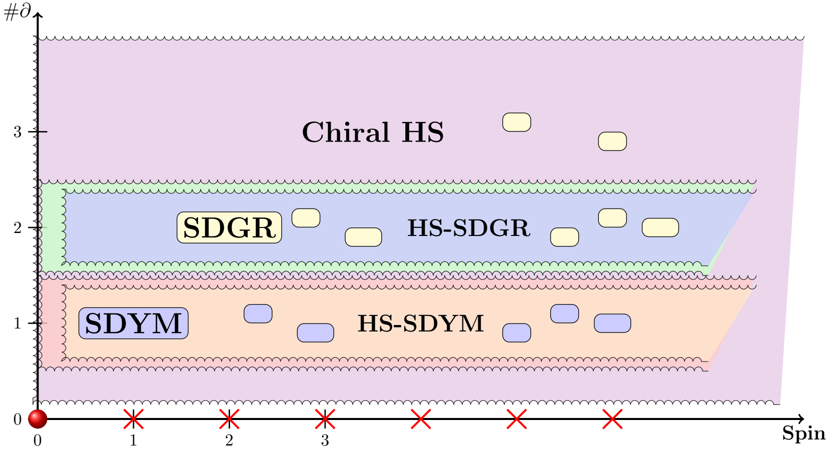
M-theory of self-dual ones and the SD-Zoo



(Ponomarev; Krasnov, E.S., Tran; Monteiro; Serrani) similar to

GR+more $\longrightarrow$ SUGRAs $\longrightarrow$ maximal (gauged) SUGRA

M-theory of self-dual theories and the SD-Zoo



Full classification of SD-theories is not yet available, but it leads to problems in number theory and deformation quantization

Chiral HiSGRA: light-cone approach

Chiral HiSGRA (Metsaev; Ponomarev, E.S.) is a 'higher spin extension' of SDYM/SDGR. It has fields of all spins $s = 0, 1, 2, 3, ...$:

$$\mathcal{L} = \sum_{\lambda} \Phi^{-\lambda} \Box \Phi^{+\lambda} + \sum_{\lambda_i} \frac{\kappa\, l_{\text{Pl}}^{\lambda_1+\lambda_2+\lambda_3-1}}{\Gamma(\lambda_1+\lambda_2+\lambda_3)} V^{\lambda_1,\lambda_2,\lambda_3} + \mathcal{O}(\Lambda)$$

HS-SDYM and HS-SDGR: $\sum_i \lambda_i = 1$ or 2. All are smooth in Λ.

Tree-level amplitudes "vanish". It is UV-finite at least at one-loop, where it gives HS-dressed SDYM's one-loop amplitudes

Covariantly: "**Poisson sigma model** in $4d$" (Sharapov, E.S, Van Dongen)

$$dC^i = \pi^{ij}(C)\, A_j\,, \qquad dA_k = \tfrac{1}{2}\partial_k \pi^{ij}(C)\, A_i \wedge A_j\,.$$

Relation to (Kontsevich) formality, gauge invariance $\leftrightarrow$ A_∞ Stokes

How else self-duality looks like?

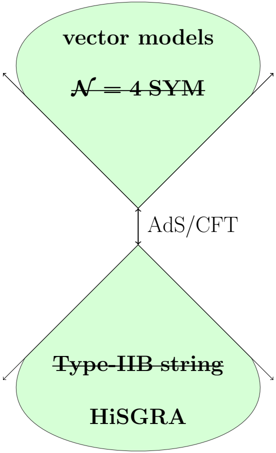
- tree-level amplitudes vanish, well, not quite ... (Guevara et al)
- UV-finite, one-loop exact $\to$ **deserve their own dualities**
- Only $\lambda_1 + \lambda_2 + \lambda_3 > 0$ participate

$$\sum_{\lambda_{1,2,3}} \boldsymbol{C_{\lambda_1,\lambda_2,\lambda_3}} [12]^{\lambda_1+\lambda_2-\lambda_3} [23]^{\lambda_2+\lambda_3-\lambda_1} [31]^{\lambda_3+\lambda_1-\lambda_2}$$

- celestial OPE associativity (Ren, Spradlin, Yelleshpur Srikant, Volovich; Serrani)
- twistor formulation; for HS: (Adamo, Herfray, Krasnov, Mason, Sharma, E.S., Tran)

Self-dual dualities:
AdS/CFT

Simplifying AdS/CFT dualities?



some features are captured by: (Vasiliev; Jevicki, Mello Koch et al; Aharony et al)

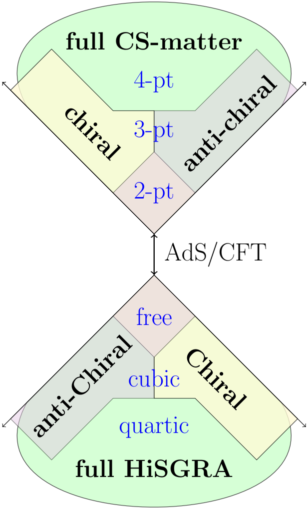
AdS/CFT simpler than Strings/SYM? HiSGRA/vector models (Klebanov, Polyakov; Sezgin, Sundell; Giombi, Yin, ...)

Not every CFT has a nice dual!

1. quasi-classical $\sim N \to \infty$
~~2~~. finitely-many fields $\sim$ SUGRA
3. local? **Deadly even with 1, 2 ok**

Only quasi-classical $G \sim N^{-1}$, but still very nonlocal (Bekaert et al; Maldacena et al; Sleight, Taronna; Ponomarev)

The HiSGRA is not local/known



Chiral HiSGRA implies: two closed sub-sectors in vector models (Sharapov, E.S.)

There are two new **self-dual CFTs!**

SDYM/SDGR capture subsectors;

All 3pt-functions computed (E.S.);

$3d$ bosonization up to 4pt (Yin, E.S.);

Self-dual CFTs?

What is a self-dual CFT ?

From AdS/CFT vantage point: **dual of something self-dual**

From CFT point: not 100% clear yet, but complex Chern–Simons level seems necessary (Aharony, Kalloor, Kukolj; Jain, Dhruva, E.S.)

In the helicity basis: $\langle J_{\lambda_1} \ldots \rangle \neq 0$ whenever $\sum_{i=1}^{n} \lambda_i \geq n-2$ for all $n = 3, 4, \ldots$, $\langle J_{\lambda_1} \ldots \rangle = 0$, otherwise.

For example, we keep $\langle T_+ T_+ T_+ \rangle$, $\langle T_+ T_+ T_- \rangle$ and set $\langle T_- T_- T_- \rangle = 0$, $\langle T_- T_- T_+ \rangle = 0$

This can be true for Chern–Simons matter theories up to ABJ, indicating that M-theory/strings can have “SD-subsectors” on AdS_4

Self-dual dualities: YM vs. SDYM

Based on "Dirichlet, Neumann, Mixed and self-dual holography: (self-dual) Yang-Mills theory", E.S., Richard Van Dongen, 2602.21658

Self-dual holography: main questions

A useful starting point is Chalmers–Siegel + Chern–Simons

$$a \int F_{\mu\nu}^2 + b\,\theta \sim a \int_M \boldsymbol{\Psi}^{AB} \boldsymbol{F}_{AB} - \frac{\boldsymbol{\epsilon}}{\mathbf{2}} \boldsymbol{\Psi}^{\mathbf{2}}_{AB} + (b-a)\textbf{CS}$$

Some of the usual questions

- Fefferman-Graham expansion
- Boundary conditions
- AdS/CFT dictionary
- propagators, amplitudes/correlators
- flat limit of correlators
- ...

Known holographic facts

Fefferman-Graham expansion:

$$A_i = a_i + z(J_i \sim E_i) + \ldots = \text{gauge field} + \text{current}$$

Dirichlet: fix a_i, $S_{\mathsf{AdS}}[a] = W_{\mathsf{CFT}}[a]$ gives $\langle J \ldots J \rangle$

Neumann: fix J_i, $S_{\mathsf{AdS}}[J] = W_{\mathsf{CFT}}[J]$ gives $\langle a \ldots a \rangle$, a better object is magnetic field/dual current $B[a] = *da$

Neumann and Dirichlet are related by a Legendre transform, also related in the bulk (Klebanov, Witten; Hartman, Rastelli; Giombi, Yin)

Mixed: fix $B \cos\gamma + iE \sin(\gamma) = F_{AB} e^{+i\gamma} + \bar{F}_{A'B'} e^{-i\gamma}$
the dual is still a gauge field, but with a Chern-Simons term

SD: $\gamma \to -i\infty$ or CS-level $\to -i$, i.e. $B + E \to 0$

SDYM must have the same FG-data, but different FG-expansion

The free equations are $\nabla^{(A}{}_{C'}\,\Phi^{B),C'}=0$ and $\nabla_B{}^{A'}\,\Psi^{AB}=0$. These are 1st order equations and boundary data is only Dirichlet

$$\begin{aligned} \text{current :}\qquad & \Psi^{AA}=\cosh(kz)\psi_0^{AA}+\tfrac{1}{k}\sinh(kz)k^A{}_B\,\psi_0^{AB}\,, \\ \text{gauge field :}\qquad & \Phi^{AA}=\cosh(kz)\phi_0^{AA}-\tfrac{1}{k}\sinh(kz)k^A{}_B\,\phi_0^{AB}\,, \end{aligned}$$

where $k_A\bar{k}_B=\vec{k}_{AB}+\epsilon_{AB}|\vec{k}|$, spinor-helicity (Maldacena, Pimentel).

Fixed choice for boundary conditions. Effectively, $\partial_z \pm |k|$ on the physical components – helicity sensitive! Φ_+ and Ψ_- are regular.

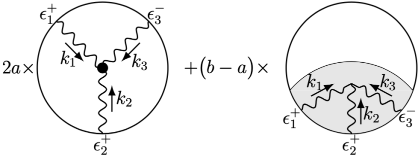
$$\Phi/\Psi=\sum_{\pm}\epsilon_{\pm}^{AB}\Phi_\pm/\Psi_\pm \qquad \epsilon_+^{AB}\sim\bar{k}^A\bar{k}^B \quad \epsilon_-^{AB}\sim k^Ak^B$$

SDYM correlators

Φ gives J_+ and Ψ gives $J_- = *da_-$ to assemble J_m

In flat space: helicity + loop suffice to separate SDYM vs. YM

At the three-point level (see also (E.S., Chowdhury et al) for light-cone)

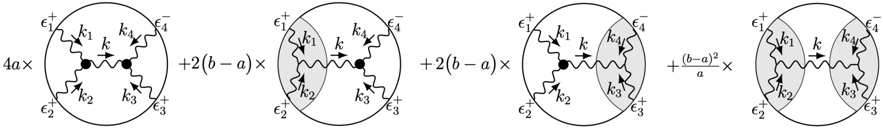


= SDYM + Chern–Simons

$$\text{SDYM} = \frac{g}{2E}\frac{\langle\bar{1}3\rangle\langle\bar{2}3\rangle}{k_1k_2}\langle\bar{1}\bar{2}\rangle\,, \qquad \text{CS} = \frac{g}{4}\frac{\langle\bar{1}\bar{2}\rangle\langle\bar{1}3\rangle\langle\bar{2}3\rangle}{k_1k_2k_3}$$

SDYM correlators

At the 4-point it is still true that the SD-limit of mixed boundary conditions in YM/Chalmers–Siegel gives SDYM.



Flat limit: all propagators integrated $\rightarrow$ flat propagator

Split SD $+$ topological is very efficient for computations

For Dirichlet the CS-term does not contribute; 4-pt for Dirichlet (Armstrong, Lipstein, Mei), Neumann, mixed and SD-limit

There is some gauge dependence since the dual is a gauge field

Self-dual dualities:
Celestial (?)

Chiral HiSGRA for celestial holography

(Ren, Spradlin, Yelleshpur Srikant, Volovich) found that Chiral HiSGRA is a solution to celestial OPE associativity; as well as all the other SD-theories (Serrani)

There is an analog of vector model AdS/CFT duality (Ponomarev):

$\Box\phi = 0$, single-trace operators $J_s \sim \phi\partial^s\phi$ are dual to HS bulk fields

(Distributional) amplitudes are invariants of the HS-algebra like in AdS/CFT, which have "collinear features"

Missing piece of the puzzle (?): (Guevara et al, 26) SD-theories do have nonvanishing amplitudes that are collinear! In HS-SDYM

$$\mathcal{A}_3 = \frac{(r3)^{2s-2}}{(r1)^{2s_1-2}(r2)^{2s_2-2}} \frac{(r3)^4 \,\mathrm{sg}(\bar{1}\bar{2})}{(r1)(r2)}\, \delta(13)\delta(23)\, \delta^2(\sum_k (rk)\bar{k}_{A'})\,.$$

Conclusions & Discussion & Speculations

- There is a Zoo of SD-theories to be uncovered, the maximal one being Chiral higher-spin gravity
- Self-dual holography: SDYM & SDGR are dual to universal subsectors of correlators. Self-dual CFTs?
- In AdS/CFT: Chern–Simons vector models have closed subsectors, which can explain 3d bosonization. Possibly the simplest AdS/CFT exactly solvable model?
- Novanishing amplitudes in all SD-theories thanks to (Guevara et al, 26) can give a celestial analogue of vector models/HS duality
- SDYM & SDGR amplitudes $\subset$ HS-invariants ...
- M-theory/String theory: self-dual subsector via ABJ

Thank you for your attention!

... backup slides ...

Asymptotic higher spin symmetries (HSS)

$$\delta\Phi_{\mu_1\dots\mu_s}(x) = \nabla_{(\mu_1}\xi_{\mu_2\dots\mu_s)} \quad \overset{AdS/CFT}{\longleftrightarrow} \quad \partial^m J_{ma_2\dots a_s} = 0$$

seem to completely fix (holographic) S-matrix to be

$$S_{\text{HiSGRA}} = \begin{cases} 1^{****}, & \text{flat space, (Weinberg)} \\ \text{free CFT, e.g. } \Box\phi = 0, & \text{asymptotic AdS, unbroken HSS}^{\dagger} \\ \textbf{Chern-Simons Matter}, & \textbf{asymptotic AdS}_4\textbf{, SB HSS}^{\diamond} \end{cases}$$

Most interesting applications are to vector models, (Klebanov, Polyakov; Sezgin, Sundell; Maldacena, Zhiboedov;[†,◇] Giombi, Yin, ...;[◇] ...)

Both Minkowski/(A)dS cases reveal certain non-localities since HSS mixes ∞ spins and derivatives, invalidating the local QFT approach

Twistor-inspired approach

Twistors treat positive and negative helicities differently:

$$\nabla_B{}^{A'}\,\Psi^{BA(2s-1)} = 0 \qquad \text{(Penrose, 1965)}$$

$$\nabla^A{}_{B'}\,\Phi^{A(2s-1),B'} = 0 \qquad \delta\Phi^{A(2s-1),B'} = \nabla^{AB'}\xi^{A(2s-2)}$$

(Hitchin, 1980) entertains a possibility to introduce a connection

$$\omega^{A(2s-2)} \ni e_{BB'}\Phi^{A(2s-2)B,B'} \qquad \delta\omega^{A(2s-2)} = \nabla\xi^{A(2s-2)}$$

where $e_{AA'}$ is the vierbein and with $H^{AB} \equiv e^A{}_{C'} \wedge e^{BC'}$ we can write

$$\boldsymbol{S = \int \Psi^{A(2s)} \wedge H_{AA} \wedge \nabla\omega_{A(2s-2)}}$$

which is also invariant under $\delta\omega^{A(2s-2)} = e^A{}_{C'}\,\eta^{A(2s-3),C'}$ to get rid of the extra component. **The simplest action for HS!**

N.B: for $s=1$ we have Ψ^{AB} and $A^{CC'}$, for $s=2$ Ψ^{ABCD} and ω^{AB}

HS-SDYM

Let's add more indices to the Charlmers-Siegel action

$$\mathbf{tr}\int \boldsymbol{\Psi}^{AB}\boldsymbol{H}_{AB}\wedge \boldsymbol{F} \quad \rightarrow \quad \sum_s \mathbf{tr}\int \boldsymbol{\Psi}^{A(2s)}\boldsymbol{H}_{AA}\wedge \boldsymbol{F}_{A(2s-2)}$$

where all A's are symmetrized inside F

$$F = d\omega + \tfrac{1}{2}[\omega,\omega] \qquad\qquad \omega = \sum_s (\omega^{A(2s)})^i{}_j\; y_A...y_A$$

Feature: describes gauge, one-derivative, interactions of higher spin fields. The higher-spin symmetry is loop algebra $\mathfrak{g}\times C[y^A]$.

Twistor formulation is available (Tran; Herfray, Krasnov, E.S.) and the HS-extension of the Ward correspondence

A beautiful improvement is in (Mason, Sharma): Chern-Simons on $\mathbb{S}^7$

The action is an extension of (Krasnov) and (Krasnov, E.S.)

$$\int \boldsymbol{\Psi}^{ABCD}\, \boldsymbol{F}_{AB} \wedge \boldsymbol{F}_{CD} \quad \to \quad \sum_{m,n} \int \boldsymbol{\Psi}^{A(n+m)}\, \boldsymbol{F}_{A(n)} \wedge \boldsymbol{F}_{A(m)}$$

where $F_{A(2s-s)}$ depends on whether $\boldsymbol{\lambda} = 0$ or $\boldsymbol{\lambda} \neq 0$:

$$\boldsymbol{\lambda} = 0 : \qquad F_{A(n)} = d\omega_{A(n)}$$

$$\boldsymbol{\lambda} \neq 0 : \qquad F = d\omega + \tfrac{1}{2}\boldsymbol{\lambda}\,\{\omega, \omega\}$$

where we define Poisson bracket on $\mathbb{R}^2$ of $f(y)$, same as $w_{1+\infty}$:

$$\{f, g\} = \epsilon^{AB}\, \partial_A f(y)\, \partial_B g(y)$$

Twistor formulation (Herfray, Krasnov, E.S.) and the HS-extension of nonlinear graviton theorem; better twistor formulation (Mason, Sharma)

Chiral HSGRA vs. Tensionless Strings

Strings on $AdS_4 \times \mathbb{CP}^3$ are dual to ABJ = Chern-Simons (k) matter with bi-fundamental matter, $N \times M$, (Chang, Minwalla, Sharma, Yin):

there is a vector-like limit $N \gg M$, where it is dual to $\mathcal{N} = 6$ $U(M)$-gauged HiSGRA, which suffers from the non-locality[1]

Inside this non-local/non-existing HiSGRA there is $\mathcal{N} = 6$ $U(M)$-gauged Chiral HiSGRA, which is local

By the same token, ABJ theory contains a "self-dual subsector", which should be dual to a "self-dual" subsector of tensionless strings

Is it possible to directly identify the Chiral subsector of tensionless strings on $AdS_4 \times \mathbb{CP}^3$?

---

[1] For Vasiliev's equations see (Boulanger et al); in general, see (Bekaert, Erdmenger, Ponomarev, Sleight, Taronna) for "non-existence" of vector model duals.