Title: Higher-Spin Charges in Gravity

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Collection/Series: Celestial Holography Summer School 2024

Date: July 24, 2024 - 3:45 PM

URL: https://pirsa.org/24070085

Abstract:

I will describe shortly what the higher-spin charges are and why they are relevant from a holographic point of view. Besides, I will emphasize the recent result according to which they are realized as Noether charges in a non-linear regime.

Canonical Realization of Higher Spin Symmetries

Lightning Talk
Celestial Holography Summer School 2024

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Motivations

- What are the *symmetries* of the $\mathcal{S}$-matrix? [Strominger, Narayanan, Himwich]
- To which extent do they constraint scattering amplitudes with soft particles? *Soft Theorems.* [Strominger, Pate, Raclariu, Pasterski, Ball]
- $w_{1+\infty}$ as symmetry of truncated EE. [Freidel, Pranzetti, Raclariu, Geiller]
- $w_{1+\infty}$ as residual gauge symmetry of twistor space. [Mason, Sharma, Adamo, Ruzziconi]
- (How) is the $w_{1+\infty}$ symmetry deformed by *interactions* (higher G_N *corrections*)?

Our Main Result

There is a non-perturbative canonical realization of a 'beyond the wedge' $w_{1+\infty}$ algebroid onto the Ashtekar-Streubel phase space $\mathcal{P}$.

- AS symplectic form:

$$\Omega_{\text{AS}} = \frac{1}{4\pi G}\int_{\mathcal{I}} \delta\bar{N} \wedge \delta C$$

What's known

- $w_{1+\infty}$ was identified as a symmetry algebra constraining *OPE* between soft gravitons. [Strominger and al.]
- A collection of Soft and Hard *higher spin charges* were then constructed on $\mathcal{P}$. [Freidel, Pranzetti, Raclariu, Geiller] Components in a $1/r$ exp. of Weyl tensor
- They satisfy the SDGR Bianchi id.: $\partial_u Q_s = DQ_{s-1} + (s+1)CQ_{s-2}$
- Their Hard *action* on soft gravitons was matched with OPE.
- These charges form a $w_{1+\infty}$ *algebra* defined by the bracket

$$\{Q(T_s), Q(T'_{s'})\}^{(1)} = Q^{(1)}\Big(\underbrace{(s+1)T_s DT'_{s'} - (s'+1)T'_{s'} DT_s}_{[T_s, T'_{s'}]^{\mathsf{W}}_{s+s'-1}}\Big) \tag{1}$$

under 2 restrictions:

  - Truncation in G_N
  - Wedge condition: $D^{s+2}T_s = 0$

Think about an extension of $\mathfrak{gbms}$ to all spins

- The W-bracket is *not* a Lie bracket for all s *outside* of the wedge

Beyond the Wedge

- Action of *time* and *field dependent* symmetry parameters $\tau_s(u,z,\bar{z})$ on $\mathcal{P}$:

$$\delta_\tau C = -D^2\tau_0 + N\tau_0 + 2DC\tau_1 + 3CD\tau_1 - 3C^2\tau_2 \qquad (2)$$

↳ *Only 3* parameters!

- δ_τ is a *Lie algebroid action*,

$$[\delta_\tau, \delta_{\tau'}]C = -\delta_{[\![\tau,\tau']\!]}C \qquad (3)$$

when τ_s satisfy a set of dual EOM: $\boxed{\partial_u \tau_s = D\tau_{s+1} - (s+3)C\tau_{s+2}}$

$\tau_s\big|_{u=0} = T_s(z,\bar{z})$

- *New* bracket

$$[\![\tau,\tau']\!]_s := [\tau,\tau']_s + \underbrace{\big(\delta_{\tau'}\tau\big)_s - \big(\delta_\tau\tau'\big)_s}_{\text{algebroid/Barnich-Troessaert}} \qquad s \geqslant -1, \qquad (4)$$

$$[\tau,\tau']_s = \underbrace{\sum_{n=0}^{s+1}(n+1)\big(\tau_n D\tau'_{s+1-n} - \tau'_n D\tau_{s+1-n}\big)}_{\text{W-bracket structure}} - \underbrace{(s+3)C\big(\tau_0\tau'_{s+2} - \tau'_0\tau_{s+2}\big)}_{\text{field dependency}}$$

Noether Representation

- Defining

$$Q_\tau = \sum_{s=-1}^{\infty} \int_S Q_s \tau_s \qquad (5)$$

↳ Plays the role of a *generating* functional!

we showed that

$$Q_\tau = \frac{1}{4\pi G} \int_{\mathcal{I}} \bar{N} \delta_\tau C \qquad (6)$$

Result

Q_τ is a *Noether* charge and generates a *beyond* the *wedge* and *non-perturbative* $w_{1+\infty}$ algebroid on $\mathcal{P}$.

$$\begin{aligned} I_{\delta_\tau} \Omega_{\text{AS}} &= -\delta Q_\tau & \{Q_\tau, O\} &= \delta_\tau O \\ Q_\tau &= I_{\delta_\tau} \Theta_{\text{AS}} & \{Q_\tau, Q_{\tau'}\} &= -Q_{[\![\tau,\tau']\!]} \end{aligned} \qquad (7)$$

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