Title: Comments on Soft Algebras from All-Plus Gluon Amplitudes

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Series: Quantum Fields and Strings

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Abstract: Celestial holography posits a duality between a theory of quantum gravity in asymptotically flat spacetime and a "celestial" conformal field theory that lives on its co-dimension two boundary. By studying soft theorems of scattering amplitudes in the bulk it was shown that there exist infinite towers of corresponding soft currents in cCFT and their algebra was calculated. In this talk I will consider a bulk theory of Yang-Mills coupled to a massive scalar and show, via soft limits, that the corresponding boundary algebra admits a level proportional to the strength of the background. I will comment on some other aspects of this deformation as well as potentially important subtleties we have encountered with our method of computing celestial amplitudes.

Zoom link: https://pitp.zoom.us/j/95423960414?pwd=RVoxc1FRRGRmL2RIMXJpbXFKZVBFdz09

COMMENTS ON SOFT ALGEBRAS FROM ALL-PLUS GLUON AMPLITUDES

wip w/ A. Strominger & W. Melton

S matrix $\longrightarrow$ celestial amplitudes live in cCFT

$\longrightarrow$ massless: Mellin transform , $q^\mu = \omega(1+z\bar{z},\ z+\bar{z},\ z-\bar{z},\ 1-z\bar{z})$

massive: Integral over hyperbolic

$$A_n(\omega_i, z_i, \bar{z}_i) \longrightarrow \mathcal{A}_n(\Delta_i, z_i, \bar{z}_i) = \left(\prod_{i=1}^{n} \int_0^\infty d\omega_i\, \omega_i^{\Delta_i - 1}\right) A_n(\omega_i, z_i, \bar{z}_i)$$

contains $\delta^{(4)}\left(\sum P_i\right) = \delta(\omega_1 - \omega_1^*)\,\delta(\omega_2 - \omega_2^*)\,\delta(\omega_3 - \omega_3^*)\,\delta(z - \bar{z})$ $\quad z$ conformal cross ratio

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Melton, Casali, Strominger added massive scalar background

...bras

...m in cCFT corresponds to the insertion of a soft operator, gravitons G_Δ, gluons $\mathcal{O}_\Delta$

...nwich, Pate, Strominger

$H^k \leftarrow$ conformal dimension

$$H^k(z,\bar z) = \lim_{\varepsilon\to 0} \varepsilon\, G_{k+\varepsilon}(z,\bar z)$$

$$H^k(z,\bar z) = \sum_{n=\frac{k-2}{2}}^{\frac{2-k}{2}} \frac{H^k_n(z)}{\bar z^{\,n+\frac{k-2}{2}}} \longrightarrow \omega^p_n = \frac{1}{k}(p-n-1)!\,(p+n-1)!\, H_n^{-2p+4}$$

$$\lim_{\varepsilon\to 0} \varepsilon\, \mathcal{O}_{k+\varepsilon}$$

$$[\omega^p_m, \omega^q_n] = (m(q-1) - n(p-1))\, \omega^{p+q-2}_{m+n}$$

$$\boxed{[S^{q,a}_n, S^{p,b}_{n'}] = -i f^{ab}{}_c\, S^{q+p-1,c}_{n+n'}}$$

Soft Algebras

Soft theorem in cCFT corresponds to the insertion of a soft operator, gravitons G_Δ,

Guevara, Himwich, Pate, Strominger

$H^k(z,\bar z) \equiv \lim_{\varepsilon\to 0} \varepsilon\, G_{k+\varepsilon}(z$ ← k conformal dimen

$$H^k(z,\bar z) = \sum_{n=\frac{k-2}{2}}^{\frac{2-k}{2}} \frac{H^k_n(z)}{\bar z^{\,n+\frac{k-2}{2}}} \longrightarrow \omega^p_n = \frac{1}{k}(p-n-1)!\,(p+n-1)!\,H_n^{-2p+4}$$

$$R^k(z,\bar z) = \lim_{\varepsilon\to 0} \varepsilon\, O_{k+\varepsilon}$$

$$[\omega^p_m, \omega^q_n] = \big(m(q-1) - n(p-1)\big)\,\omega^{p+q-2}_{m+n}$$

$$\boxed{[S^{q,a}_n, S^{p,b}_{n'}] = -if^{ab}{}_c\, S^{q+p-1,c}_{n+n'}}$$

$$\mathcal{L} = \frac{1}{2}\partial^\mu \varphi \, \partial_\mu \varphi - \frac{M^2}{2}\varphi^2 - \frac{1}{2}\mathrm{Tr}\, F_{\mu\nu}F^{\mu\nu} - \frac{\mu}{4}\varphi\, \mathrm{Tr}\, F^{+}_{\mu\nu} F^{\mu\nu,+}$$

$$A(\varphi, 1^+ \ldots n^+) = \frac{\mu M^4}{\langle 12\rangle\langle 23\rangle \ldots \langle n1\rangle} \quad , \quad \mathcal{A}(1^+ \ldots n^+) \equiv \int d^4p \;\; \phi_B(p) \left[\prod \int_0^\infty d\omega_i \, \omega_i^{\Delta_i}\right.$$

Usual: φgg : usual z-dependence $\times \; B\left(\frac{\Delta_{12}+\Delta_3}{2} ; \frac{\Delta_{21}+\Delta_3}{2}\right)$

Our: usual z $\times \; B\left(\quad \right) \times$ 4 Gamma functions

Two methods:

2 write δ a

p

$\mathrm{Tr}\, F_{\mu\nu} F^{\mu\nu} - \frac{\mu}{4} \varphi\, \mathrm{Tr}\, F^{+}_{\mu\nu} F^{\mu\nu,+}$

$$, \quad \tilde{A}(1^+ \ldots n^+) \equiv \int d^4 p \; \phi_B(p) \left[\prod_i \int_0^\infty d\omega_i\, \omega_i^{\Delta_i - 1} \right] A(p, 1^+ \ldots n^+)$$

$$\times \; B\left(\frac{\Delta_{12} + \Delta_3}{2} , \frac{\Delta_{21} + \Delta_3}{2} \right)$$

4 Gamma functions

Two methods: ① use δ-function to do p-integral

② write δ as $\int_{\text{position}}$ and do Mellin, then

$$\frac{\mu}{4}\,\varphi\,\mathrm{Tr}\,F^{+}_{\mu\nu}F^{\mu\nu,+}$$

$$\ldots n^{+}) \equiv \int d^4p\; \phi_B(p)\left[\prod \int_0^\infty d\omega_i\, \omega_i^{\Delta_i - 1}\right] A(p, 1^{+} \ldots n^{+})$$

$$\Delta_3 \quad ; \quad \frac{\Delta_{21} + \Delta_3}{2}$$

Two methods: ① use δ-function to do p-integral

② write δ as $\int$ and do Mellin, then

position

...tions

$$\frac{K}{2}\log|x|^2$$

$$\mathcal{L} = \frac{1}{2}\partial^\mu\varphi\,\partial_\mu\varphi - \frac{M^2}{2}\varphi^2 - \frac{1}{2}\mathrm{Tr}\,F_{\mu\nu}F^{\mu\nu} - \frac{\mu}{4}\varphi\,\mathrm{Tr}\,F_{\mu\nu}^{+}F^{\mu\nu,+}$$

$$A(\varphi, 1^+ \ldots n^+) = \frac{\mu M^4}{\langle 12\rangle\langle 23\rangle\ldots\langle n1\rangle}, \quad \mathcal{A}(1^+\ldots n^+) \equiv \int d^4p \;\; \phi_B(p) \left[\prod \int_0^\infty d\omega \right.$$

Usual: φgg : usual z-dependence $\times\; B\left(\frac{\Delta_{12}+\Delta_3}{2}, \frac{\Delta_{21}+\Delta_3}{2}\right)$

Our: usual z $\times\; B(\quad) \times$ 4 Gamma functions

Two meth

(2) write

$$\frac{\kappa}{2}\log|x|^2$$