Title: Celestial Chiral Algebras of self-dual Black Holes

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Abstract:

This talk is based on work in progress with Giuseppe Bogna. We consider the twistor description of classical self-dual Einstein gravity in the presence of a cosmological constant and a defect operator wrapping a certain $\mathbb{CP}^1$. The backreaction of this defect deforms the flat twistor space to that of quaternionic Taub-NUT space, a certain self-dual limit of a family of Kerr Taub-NUT AdS black holes. We discuss a 2-parameter family of Lie-algebras depending on the mass of the black hole and the cosmological constant. In various limits it reduces to algebras which were previously studied in the context of celestial holography and are closely related to $w_{1+\infty}$.

Celestial Chiral Algebras of self-dual Black Holes

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arXiv:24XX.XXXXX with G.Bogna
based on
arXiv:2403.18011 with R. Bittleston, G. Bogna, A. Kmec, L. Mason, D. Skinner
arXiv:2305.09451 with R. Bittleston and D. Skinner

Motivation and Summary

Bulk spacetimes in known top-down constructions of celestial holography have a twistor space which arises from some backreaction (e.g. Burns and Eguchi-Hanson space). [Costello, Paquette, Sharma '23, '22], [Bittlestons talk, Costellos talk '24]

Self-dual limits of certain black hole metrics with $\Lambda \neq 0$ have this property.

[Bogna, SH - to appear]

Their twistor space leads to a 2-parameter deformation of $Lw_\wedge$. [Bogna, SH]

Pedersens Metric as self-dual Black Hole

- Kerr Taub-NUT AdS$_4$ is Einstein with $\Lambda = -3/l^2$. [Plebanski, Demianski '76]

$$ds^2 = -\frac{\Delta}{\Sigma}\left(\mathrm{d}t + (2n\cos\theta - a\sin^2\theta)\frac{\mathrm{d}\phi}{\Xi}\right)^2 + \frac{\Delta_\theta}{\Sigma}\left(a\,\mathrm{d}t - (r^2+a^2+n^2)\frac{\mathrm{d}\phi}{\Xi}\right)^2 + \frac{\Sigma}{\Delta}\,\mathrm{d}r^2 + \frac{\Sigma}{\Delta_\theta}\sin^2\theta\,\mathrm{d}\theta^2\,,$$

$$\Sigma = r^2 + (n + a\cos\theta)^2 \qquad \frac{\Delta_\theta}{\sin^2\theta} = 1 - \frac{4an\cos\theta}{l^2} - \frac{a^2\cos^2\theta}{l^2} \qquad \Xi = 1 - \frac{a^2}{l^2}$$

$$\Delta = r^2 + a^2 - 2mr - n^2 + \frac{3(a^2-n^2)\,n^2 + (a^2+6n^2)\,r^2 + r^4}{l^2}\,.$$

- Type D in Petrovs classification i.e. the only component of the (anti-)self-dual Weyl-tensor is ψ_2 ($\tilde{\psi}_2$), which vanishes for

$$m = \pm i n\left(1 - \frac{a^2 - 4n^2}{l^2}\right).$$

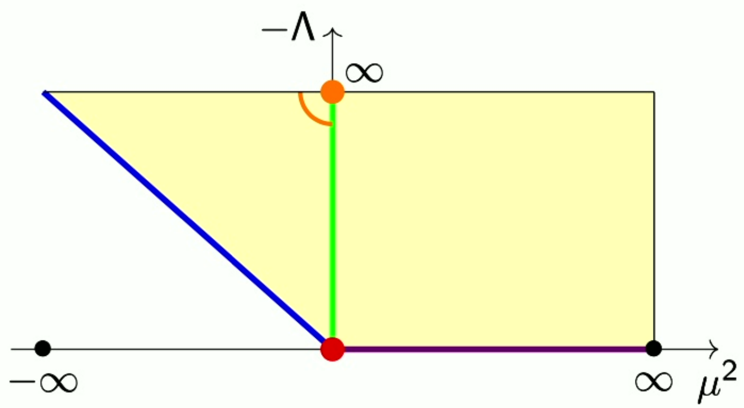
- For $a = 0$, the resulting Euclidean anti-self-dual metric [Gibbons, Pope '78], [Chamblin, Emparan, Johnson, Myers '98] is diffeomorphic to

$$ds^2 = \frac{4}{(1-r^2/l^2)^2}\left(\frac{1+\mu^2 r^2}{1+\mu^2 r^4/l^2}\,\mathrm{d}r^2 + r^2(1+\mu^2 r^2)(\sigma_1^2+\sigma_2^2) + r^2\,\frac{1+\mu^2 r^4/l^2}{1+\mu^2 r^2}\,\sigma_3^2\right),$$

which has been constructed through twistor methods. [Pedersen '85]

Various Limits

- Pedersen's metric has various limits: a singular double cover of Eguchi-Hanson space, self-dual Taub-NUT, $\widetilde{\mathbb{CP}}^2$, Euclidean AdS_4, $\mathbb{R}^4$.



- For $\mu^2 \leq 0$, Pedersens metric is conformally equivalent to a family of scalar-flat Kähler metrics, which limits to Burns space. [Lebrun '91]
- Pedersens twistor space arises from backreaction with a $\Lambda \neq 0$ infinity twistor. Leads to a 2-parameter algebra limiting to the expected Eguchi-Hanson and AdS_4 algebras (up to $\mathbb{Z}_2$-quotients). [Bogna, SH to appear]

CCA of Pedersens metric

2-parameter deformation of $Lw_\wedge$. Not as bad as it looks! [Bogna, SH to appear]

$$\{V[p,q,2i,2j],V[r,s,2k,2l]\}=(ps-qr)V[p+r-1,q+s-1,2(i+k),2(j+l)]$$
$$+4\Lambda(il-jk)V[p+r,q+s,2(i+k-1)+1,2(j+l-1)+1]$$
$$-\Lambda\mu^2((p-q)(k+l)-(r-s)(i+j))V[p+r+1,q+s+1,2(i+k-1),2(j+l-1)]\,,$$
$$\{V[p,q,2i,2j],V[r,s,2k+1,2l+1]\}=(ps-qr)V[p+r-1,q+s-1,2(i+k)+1,2(j+l)+1]$$
$$+2\Lambda(i(2l+1)-j(2k+1))V[p+r,q+s,2(i+k),2(j+l)]$$
$$+4\Lambda^2\mu^2(il-jk)V[p+r+2,q+s+2,2(i+k-1),2(j+l-1)]$$
$$-\Lambda\mu^2((p-q)(k+l)-(r-s)(i+j))V[p+r+1,q+s+1,2(i+k-1)+1,2(j+l-1)+1]\,,$$
$$\{V[p,q,2i+1,2j+1],V[r,s,2k+1,2l+1]\}=(ps-qr)V[p+r-1,q+s-1,2(i+k+1),2(j+l+1)]$$
$$+\Lambda\mu^2(ps-qr)V[p+r+2,q+s+2,2(i+k),2(j+l)]$$
$$+\Lambda((2i+1)(2l+1)-(2j+1)(2k+1))V[p+r,q+s,2(i+k)+1,2(j+l)+1]$$
$$+4\Lambda\mu^2(il-jk)V[p+r+2,q+s+2,2(i+k-1)+1,2(j+l-1)+1]$$
$$-\Lambda\mu^2((p-q)(k+l)-(r-s)(i+j))V[p+r+1,q+s+1,2(i+k),2(j+l)]$$
$$-\left(\Lambda\mu^2\right)^2((p-q)(k+l)-(r-s)(i+j))V[p+r+3,q+s+3,2(i+k-1),2(j+l-1)]\,.$$

Outlook

- Properties in $(2,2)$ signature and role of angular momentum $(a \neq 0)$ [Crawley, Guevara, Miller, Strominger '21], [Crawley, Guevara, Himwich, Strominger '23] when $\Lambda \neq 0$?
- Relation between self-dual and physical black holes [Guevara, Kol '23] with $\Lambda \neq 0$?
- Is it possible to obtain Pedersens twistor space from a backreaction in the Burns holography setup [Costello, Paquette, Sharma '23, '22] or more recent top-down constructions [Bittlestons talk, Costellos talk '24]?