Marginal Operators from Celestial Diamonds

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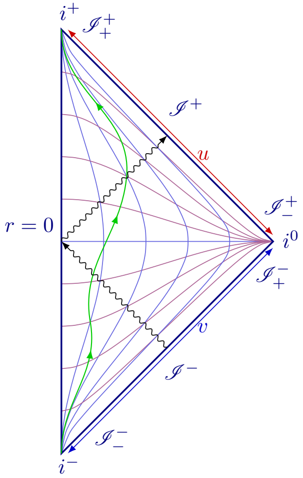
Motivation: Holography in $\Lambda = 0$ Spacetimes



- Holography in bulk AdS spacetimes is far better understood than in spacetimes with $\Lambda \geq 0$
- Celestial holography proposes that quantum gravity in asymptotically flat spacetimes ($\Lambda = 0$) is fully encoded in a co-dimension-2 CFT living on a cut of null infinity
- Motivating question: **What intrinsic properties does a *celestial* CFT possess?**
- Possible answers might lie in studying the space of celestial CFTs related by marginal deformations
- OPEs of marginal operators encode conformal manifold geometry:

$$\mathcal{M}_I(z)\mathcal{M}_J(w) \sim \frac{g_{IJ}}{|z-w|^4} + \Gamma^K_{IJ}\mathcal{M}_K(w)\delta^{(2)}(z-w) + \text{Reg}$$

Celestial CFT Spectrum

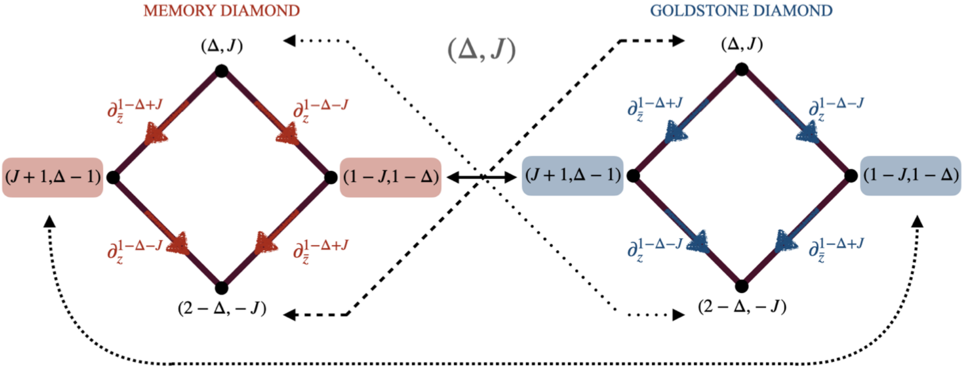


Figure: Memory and Goldstone diamonds are distinguished by their values of Δ. Memory: $\Delta = 1 - n$, Goldstone: $\Delta = 1 + n$, $n \in \mathbb{Z}_{\geq 0}$. Together, they form a complete basis for cCFT spectrum. Left/right corners of memory diamond encode conformally soft operators that generate CFT Ward identities. Arrows denote symplectically paired operators.

Exactly Marginal Operators in Celestial Holography

- In 2D CFT, exactly marginal operators are those with $\Delta = 2, J = 0$
- We construct composite operators that are exactly marginal for all $n \in \mathbb{Z}_{\geq 0}$: $\mathbb{M}_n(z,\bar{z}) \equiv : \mathcal{C}^{\mp}_{\Delta=1+n} \mathcal{O}^{\pm}_{\Delta=1-n} : (z,\bar{z})$.
- For example: leading soft gluons in bulk are dual to Kac-Moody currents J^a in celestial CFT.
- Define the exactly marginal operator $\mathbb{M}(z,\bar{z}) =: J^a \bar{J}^a : (z,\bar{z})$. Taking an OPE we find

$$\mathbb{M}(z,\bar{z})\mathbb{M}(w,\bar{w}) \sim \frac{2Nk^2}{|z-w|^4} + \frac{N}{2\pi^2}\delta^{(2)}(z-w)\mathbb{M}(w,\bar{w}) + \mathrm{Reg} \tag{1}$$

  showing the same structure as general marginal OPEs.
- Celestial correlators (dual to bulk S-matrix elements) should carry a set of soft vacuum labels $\langle X \rangle_{\{\mathcal{C}_n\}}$
- These labels shift upon a marginal deformation of the holographic theory:

$$\langle X \rangle_{\{\mathcal{C}_n - \delta\mathcal{C}_n\}} = \langle X e^{-\lambda_n \int \mathbb{M}_n} \rangle_{\{\mathcal{C}_n\}} \tag{2}$$

- Takeaway: **Marginal deformations of celestial CFTs exist and encode bulk vacuum transitions in asymptotically flat spacetime**

Thank you!

Figure: Link to paper: 2511.20807