# Celestial Holography



I. General remarks

II. Roadmap to CCFT

III. Summary

→ Discussion Session


Tomasz Taylor

Northeastern University

Strings 7/2/21

# I. General remarks:

1. $D = 4$ (nothing extra 

)

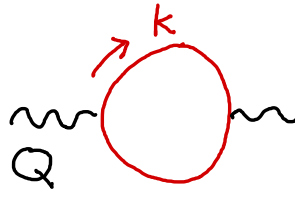
- soft theorems $\longleftrightarrow$ Ward identities (asymptotic symmetries)

**IR**

$\frac{1}{\hbar\omega}$ IR singularities in tree amplitudes in any $D$

... but too much phase space $\frac{d^{D-1}\vec{k}}{2E}$

no bremmstrahlung in $D > 4$

similarly 

convergent as $Q \to 0$ in $D > 4$

(T&Veneziano, 1988)

special interplay IR-UV in $D = 4$

(Arkani-Hamed, Pate, Radamu-S)

- celestial $CS_2(z, \bar{z})$ at null $\infty$

natural complex structure $\to$ 2D CFT

Lorentz $\to$ conformal $SL(2, \mathbb{C})$

# 2. Supersymmetry ( ... sorry 

)

$$\{Q, \bar{Q}\} \sim P$$

$$D=4: \quad P_\mu \sim \omega \left(1 + z\bar{z},\ z+\bar{z},\ -i(z-\bar{z}),\ 1 - z\bar{z}\right)$$

(super) translations are non-holomorphic


NO 2D susy in Super $BMS_{D=4}$

Fotopoulos, Stieberger, T, Zhu

Narayanan

Iacobacci, Mück

Pasterski, Puhm

Jiang

Brandhuber, Brown ...

⋮

# 3. Strings (more subtle  )

no obvious left-right ($z-\bar{z}$) decoupling, but...

celestial amplitudes with gravitons are UV divergent already at the TREE level: $\int_0^\infty d\omega\, \omega^{\cdots N_g}$

need $e^{-\omega} \sim e^{-|s|}$

suppression at $\omega \to \infty$

→ strings

$s \to \infty$ $\quad -\frac{t}{s} = z$ fixed : Gross-Mende saddle p.

$CS_2$

Mellin's $\sum \Delta \to \infty$ : $z \equiv$ vertex position

$V(z)$

→ string worldsheet pinned to $CS_2$

(Steeberger, T)

start off on the right foot

1. ✓
2. ✓
3. ✓

# II. Roadmap to CCFT

(and roadblocks ☺)

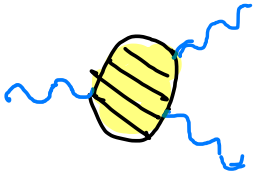
goal: describe 4D physics (YM, GR...) as 2D CFT

... let's start from perturbative YM


- office work: connections, symmetries, motives ... celestial diamonds, $W_\infty$
- field work: look at amplitudes
  conformal blocks

celestial amplitudes (Mellin-transformed to boost basis) $\longleftrightarrow$ CCFT correlators of primary fields

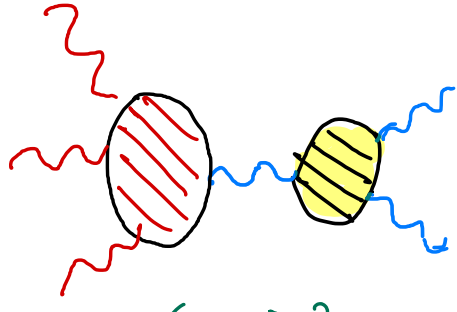
# Basic building CFT blocks: 3-pt functns from 3-pt amplitudes



$= 0$ ($m = 0$ on-shell constraints)

OOPS!

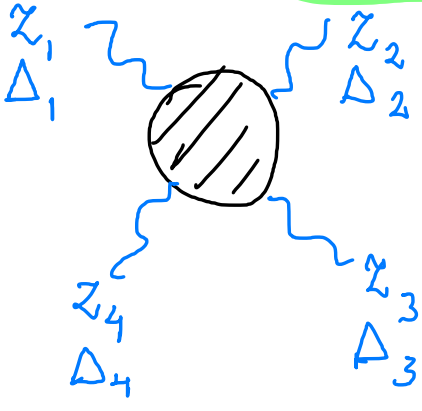
...but OPE's OK :



↳ change $(3,1)$ to $(2,2)$?


Celestial torus Atanasov, Ball, Melton, Radarui, S.

→ 4-pt functions (cross-ratio)




$$\mathcal{G}_{\Delta_i}\left(z = \frac{z_{12}\, z_{34}}{z_{13}\, z_{24}}\right)$$

$\mathrm{Re}(z)$ : scattering ∠

$\mathrm{Im}(z)$ : aplanarity

$$\mathcal{G}(z) \sim \underbrace{\delta(z-\bar{z})}\, R(z)$$

planar scattering


not a typical CFT

Conformal block decomposition

Lam, Shao
Nandan, Schreiber, Volovich, Zlotnikov
Law, Zlotnikov
Banerjee, Ghosh...
Eberti, Sharma, ...
Campiglia, Laddha
⋮

Atanasov, Melton, Radarin, S

Fan, Fotopoulos, Stieberger, T, BIN ZHU

Blocks with $\Delta = M + i\lambda$

$J = -M, \ldots M$

various gauge reps

$\Rightarrow \infty$ number of Verma modules

# CCFT looks more "maximal" than "minimal"

Open problems:


1. Need more refined relation amplitudes $\longleftrightarrow$ CFT correlators

→ 4D asymptotics $\longleftrightarrow$ 2D asymptotics

2. Role of 4D kinematics in 2D CFT

3. Understand spectrum of conf. blocks

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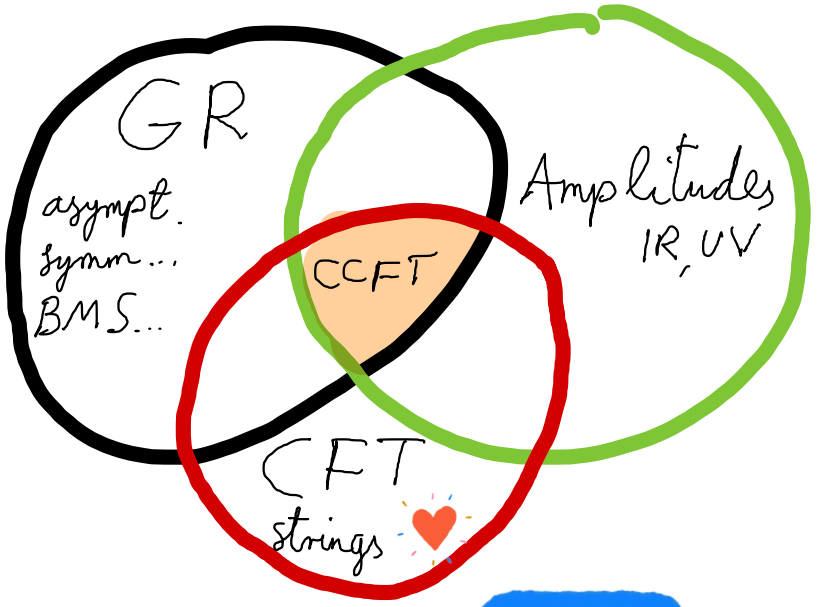
# III. Summary

Celestial holography describes 4D physics in the framework of 2D CFT on celestial sphere




THANK YOU,