Bounds on Regge growth of flat space scattering from bounds on chaos

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Motivation

- It is interesting to classify all consistent graviton S-matrix.
- String theory provides many examples of consistent scattering amplitude. Every possible compactification gives different S-matrix. This makes the classification very difficult.
- In $g_s \to 0$ all known consistent amplitudes reduces to either Einstein Gravity or Type II or heterotic string theory.
- Chowdhury et. al. conjectured, these three examples are the only consistent gravitational S-matrices.
- This is also very hard to show. If we further restrict to finite number of poles then, only consistent classical gravitational S-matrix whose exchange poles are bounded in spin is the Einstein S-matrix.

Chowdhury et. al. (1910.14392)

Motivation

- In $D < 6$ the above conjecture is indeed true provided a physically motivated constraint on S-matrix is true, called Classical Regge Growth (CRG) conjecture in 1910.14392.

  CRG conjecture: The S-matrix of a consistent classical theory never grows faster than s^2 at fixed t- at all physical values of momenta and for every possible choice of the normalized polarization vector ϵ.

- Is this CRG conjecture true? We have given a clear argument for CRG conjecture using "a bound on chaos" and AdS/CFT.

Maldacena et. al. (1503.01409)

Our Work: Set up (2102.03122)

- We have considered a tree level four point function of scalar, photon and gravitons inserted in AdS_{d+1} boundary generated from contact interaction.

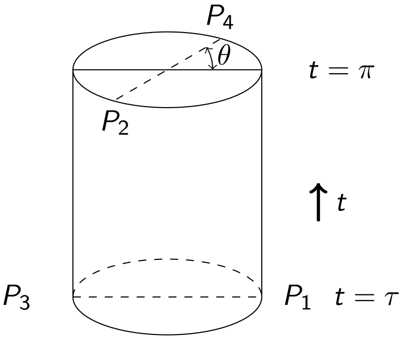


Figure: Insertion points in global AdS

- These two parameters (τ, θ) explores three different causal configurations.

MSZ (1509.03612)

Our Work (2102.03122)

- This configuration explores three different causal structures as τ decreases from π to 0.
- $\pi \geq \tau > \pi - \theta$: Euclidean.
- $\pi - \theta \geq \tau > \theta$: Causally Regge. Here chaos bound applies. It tells us, the amplitude cannot diverge faster than $\frac{1}{\sigma}$ in small $\sigma\ \left(\sim \theta^2\right)$.
- $\theta \geq \tau > 0$: Causally Scattering. Here physical scattering can happen. In this sheet using large radius limit coefficient of bulk point singularity is identified with the flat space scattering amplitude.

$$G_{singular} \sim \frac{1}{\rho^{\Delta+r-3}} \frac{\sqrt{1-\sigma}^{\Delta+r-4}}{\sqrt{\sigma}^{\Delta+r-2}} \int d\Omega_{D-3} d\zeta \frac{\sinh^{D-3}\zeta}{(\cosh\zeta)^{\Delta+r-3}} \tilde{S}(\omega)$$

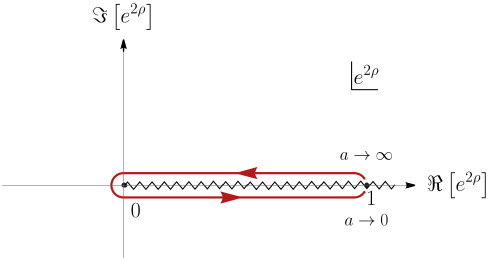
$\rho \sim \tau/\theta$ and $\Delta = \sum \Delta_i$, total scalling dimension of four insertions.

HPPS (0907.0151)

Analytic Continuation at $\sigma \to 0$

$$G_{singular} \sim \frac{1}{\sigma^{A-1}} H(\rho) + \cdots$$

Figure: Analytic continuation of $H(\rho)$ in $e^{2\rho}$ space



- We related these two different sheets through analytic continuation. This relation translates chaos bound in one sheet to CRG bound in another sheet. 2102.03122

Summary and Future directions

- We have done this calculation only for contact interactions. It is very important to see the same conjecture holds true also for exchange diagrams.
- We have taken flat space limit of AdS and used AdS/CFT to show the CRG conjecture. It would be satisfying to get direct bulk argument for the CRG conjecture without the use of AdS/CFT.
- It is also interesting to see the leading singularity we get from flat space classical String scattering amplitude using the relation.
- Another interesting direction is, what happens for incoming massive particles?

Thank you!

Why tree level does not depend on compactification?

- Type II genus g, n-graviton scattering amplitude on $R^p \times M_{10-p}$:

$$\mathcal{A} = \int dz d\tau \langle V_1(z_1) V_2(z_2) \cdots V_n(z_n) \rangle_{S_\tau}^{R^p \times M_{10-p} + ghosts}$$

- Graviton vertex operators lie entirely in the $R^p + \mathrm{ghosts}$:

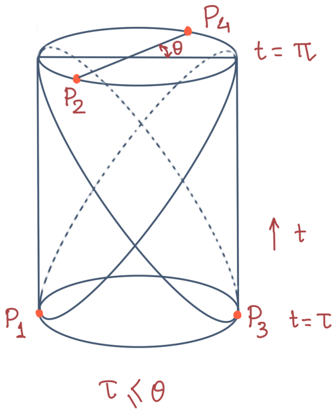
$$\mathcal{A} = \int dz Z_{M_{10-p}}(S_\tau) \left(\int d\tau \langle V_1(z_1) \cdots V_n(z_n) \rangle_{S_\tau}^{R^p \times M_{10-p} + ghosts} \right)$$

- In the special case $g = 0$,

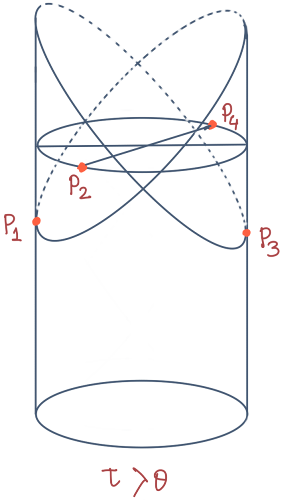
$$\mathcal{A} = Z_{M_{10-p}}(S^2) \left(\int d\tau \langle V_1(z_1) \cdots V_n(z_n) \rangle_{S^2}^{R^p \times M_{10-p} + ghosts} \right)$$

Note the only dependence on M_{10-p} is through a single multiplicative constant $Z_{M_{10-p}}(S^2)$ which sets the effective value of the p dimensional Newton constant.

Two different sheets: Scattering and Regge



Scattering configuration



Regge configuration