Title: Asymptotic symmetries for logarithmic soft theorems

Speakers: Sangmin Choi

Collection/Series: Celestial Holography Summer School 2024

Date: July 24, 2024 - 3:15 PM

URL: https://pirsa.org/24070077

Abstract:

In the last few years, a remarkable link has been established between the soft theorems and asymptotic symmetries of quantum field theories: soft theorems are Ward identities of the asymptotic symmetry generators. In particular, the tree-level subleading soft theorems are the Ward identities of the subleading asymptotic symmetries of the theory, for instance divergent gauge transformation in QED and superrotation in gravity. However, it is known that the subleading soft theorems receive quantum corrections with logarithmic dependence on the soft photon/graviton energy. It is therefore natural to ask how the quantum effects affect the classical (tree-level) symmetry interpretation. In this talk, we explore this question in the context of scalar QED and perturbative gravity. We show that the logarithmic soft theorems are the Ward identities of subleading asymptotic symmetries that arise from relaxed boundary conditions which take long-range interactions into account.

UNIVERSITY OF AMSTERDAM

European Research Council
Established by the European Commission

Asymptotic Symmetries for Log Soft Theorems

Sangmin Choi

Celestial Holography Summer School — Lightning Talk

Based on 2403.13053 and WIP with Alok Laddha and Andrea Puhm

ERC STARTING GRANT HOLOHAIR 852386

Asymptotic Symmetries for Log Soft Theorems

- Over the last decade, a remarkable link has been established between the soft theorems of QFTs and the Ward identities of asymptotic symmetries:

Leading soft graviton theorem	$\Longleftrightarrow$	Supertranslation
Subleading (tree-level) soft graviton theorem	$\Longleftrightarrow$	Superrotation
Leading soft photon theorem	$\Longleftrightarrow$	Superphaserotation (LGT)
	$\cdots$	

Soft theorem

Ward identity

$$\lim_{\omega\to 0} A_{n+1}(\omega\hat{q},\pm) = \frac{1}{\omega} S_0^{\pm}(\hat{q}) A_n + \cdots \quad \Longleftrightarrow \quad \langle \mathrm{out}|(Q^+\mathcal{S} - \mathcal{S}Q^-)|\mathrm{in}\rangle = 0$$

- More recently, Sahoo and Sen have shown that quantum loops give rise to a new soft theorem, whose soft factor is logarithmic in the soft energy:

$$\lim_{\omega\to 0} A_{n+1}(\omega\hat{q},\pm) = \frac{1}{\omega} S_0^{\pm}(\hat{q}) A_n + \underbrace{\ln\omega\, S_{\ln}^{\pm}(\hat{q}) A_n}_{\text{logarithmic soft theorem !}} + O(\omega^0)$$

- Therefore it is natural to ask:

$$\boxed{\text{What is the asymptotic symmetry associated with the logarithmic soft theorem?}}$$

- We show that it is the *same* tree-level subleading symmetry (e.g. superrotation), with the fact that particles are *not free* at large times. For instance,

$$\varphi(\tau, y) \quad \overset{\tau\to\infty}{=} \quad \frac{\sqrt{m}e^{-im\tau}}{2(2\pi\tau)^{3/2}}\Big(b_{\ln}(y)\ln\tau + b(y) + \cdots\Big) + \text{h.c.}$$

Coulombic term
due to long-range interactions

free data

- The superrotation charge diverges as $\tau \to \pm\infty$ and has to be regularized,

$$Q^{\pm} = \ln\Lambda^{-1}\, Q^{\pm}_{\ln} + Q^{\pm}_{\text{fin}}$$

- The Ward identity $\langle \text{out}|(Q^+S - SQ^-)|\text{in}\rangle = 0$ is finite as $\Lambda \to 0$,

$$\lim_{\omega\to 0} \cancel{\ln\Lambda^{-1}}\partial_\omega\omega^2\partial_\omega A_{n+1}(\omega\hat{q}, \pm) = \cancel{\ln\Lambda^{-1}} S^{\pm}_{\ln} A_n + \cancel{O(\Lambda^0)}$$

projects out $\ln\omega$ term !

One finds that this is the logarithmic soft theorem!