Bootstrapping One-Loop Inflation Correlators with the Spectral Decomposition [JHEP 04 (2023) 103]

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Background

The inflation correlators are useful probes of new heavy particles and their interactions at the inflation scale. In particular, heavy particles can leave distinct oscillatory shapes in various soft limits of n-point inflation correlators, known as cosmological collider (CC) signals.

In many CC models, the leading signals appear from 1-loop massive exchanges instead of tree level exchanges. However, massive 1-loop inflation correlators is hard to compute, and full analytical results had been unavailable in the literature.

In this work, we obtain for the first time the full analytical result for a class of 4pt and 3pt correlators with 1-loop massive scalar exchanges using the techniques of spectral decomposition in dS.

Methods

1. We define a loop seed integral (LSI) to which the computation of many 1-loop correlators can be reduced.
2. We use the 1-loop spectral density in EdS and analytically continue it to real-time dS. The LSI is then reduced to a spectral integral over the tree correlator, weighted by the spectral density (Fig. 1)

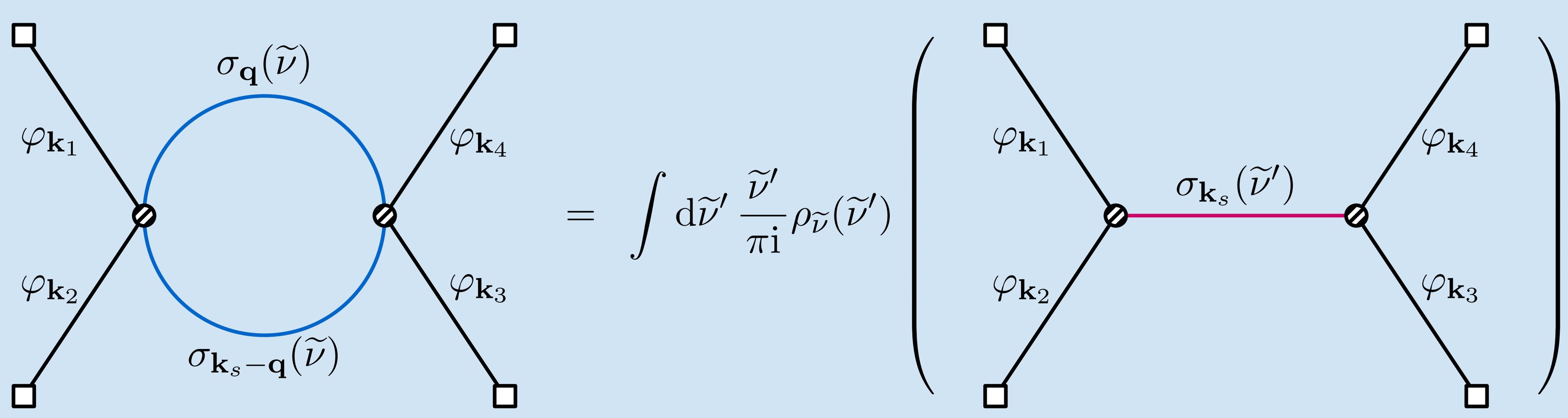

Figure 1: Spectral decomposition of 1-loop inflation correlator

3. We analysis the pole structures of the spectral integrand and finish the spectral integral in Fig. 1 by the residue theorem.

Result

1. The analytical expression of the loop seed integral can be divided into four terms according to their analytical properties in the squeezed limit: a nonlocal signal, a local signal, a logarithmic tail (vanishes in 4d), and a background:

$$\mathcal{J}_{\tilde\nu}(r_1,r_2)\sim G_{\rm NS}(r_1,r_2)(r_1r_2)^{\pm 2i\tilde\nu}+G_{\rm LS}(r_1,r_2)\left(\frac{r_1}{r_2}\right)^{\pm 2i\tilde\nu}$$
$$+G_{\rm LT}(r_1,r_2)\log r_2+G_{\rm BG}(r_1,r_2)$$

Here $r_1=\frac{k_s}{k_1+k_2}$, $r_2=\frac{k_s}{k_3+k_4}$, and $\tilde\nu\equiv\sqrt{m^2-\frac{9}{4}}$.

Result (continued)

2. The full expression for the 4pt correlator is greatly simplified in the doubly squeezed limit $r_1\ll r_2\ll 1$:

$$\widehat{\mathcal{J}}_{\rm NS}=\frac{4^{1+2i\tilde\nu}\sec(2\pi i\tilde\nu)}{\pi^2}\frac{(1+i\tilde\nu)\Gamma^2[\frac{3}{2}+i\tilde\nu,\frac{5}{2}+i\tilde\nu]}{\Gamma(4+4i\tilde\nu)}(r_1r_2)^{3/2+2i\tilde\nu}+\text{c.c.},$$

$$\widehat{\mathcal{J}}_{\rm LS}=-\frac{\sec(2\pi i\tilde\nu)}{4\sqrt{\pi}}\Gamma\left[\begin{matrix}\frac{3}{2}+i\tilde\nu,\frac{5}{2}+i\tilde\nu,1-2i\tilde\nu\\ 1+i\tilde\nu,1+i\tilde\nu,-\frac{1}{2}-2i\tilde\nu\end{matrix}\right]\left(\frac{r_1}{r_2}\right)^{3/2+2i\tilde\nu}+\text{c.c.},$$

$$\widehat{\mathcal{J}}_{\rm BG}=-24\left[\tilde\rho^{\rm dS}_{\tilde\nu}(-\tfrac{5i}{2})-\frac{1}{(4\pi)^2}\log\mu_R^2\right]\left(\frac{r_1}{r_2}\right)^{5/2}$$

3. In the 4pt function (Fig. 2), the signal dominates over the background in the single squeezed limit (r_1<<1, r_2 fixed). In the 3pt, there is no parameter space where the signal dominates over the background (Fig. 3).

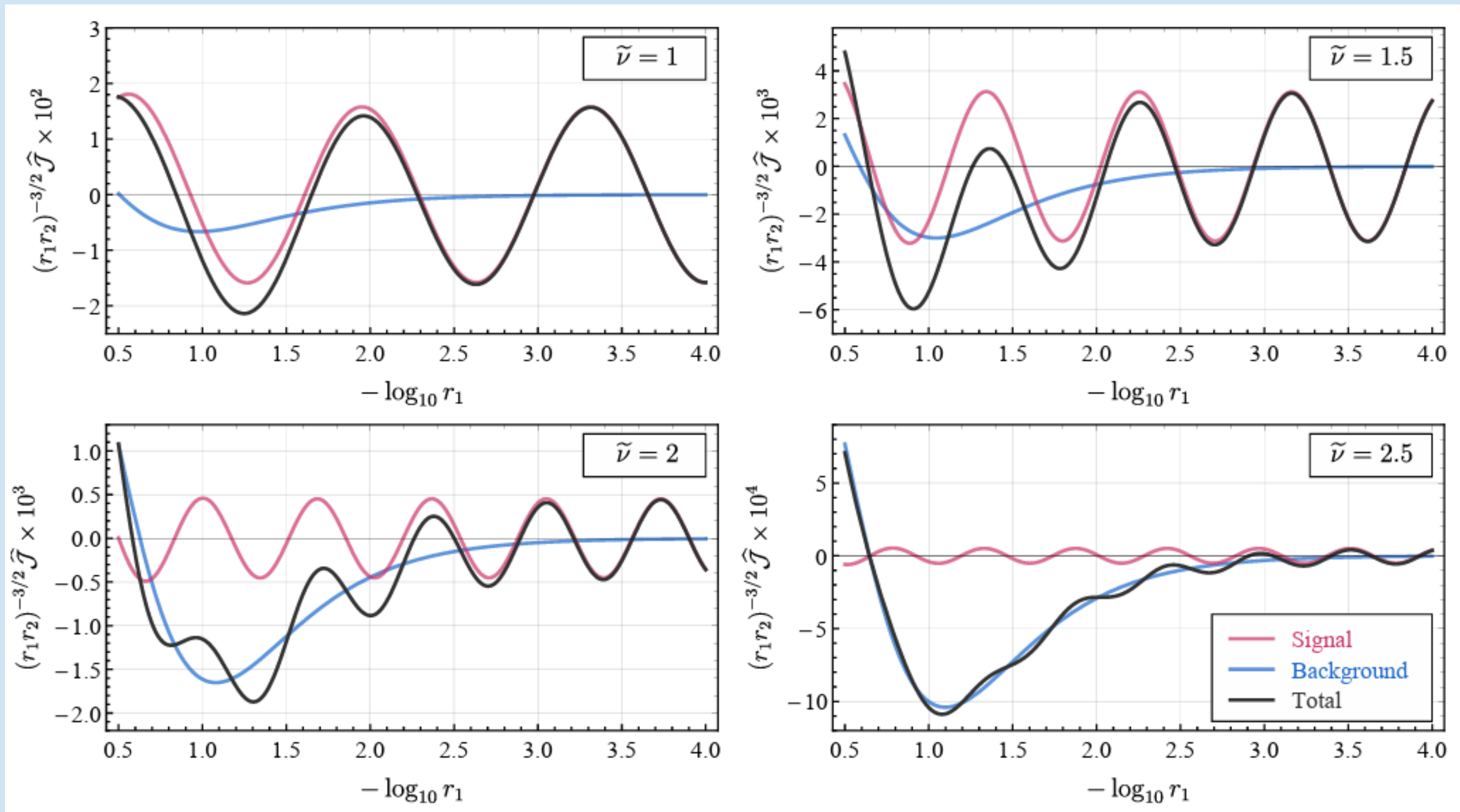

Figure 2: The 1-loop 4pt correlator with mass parameter $\tilde\nu$.

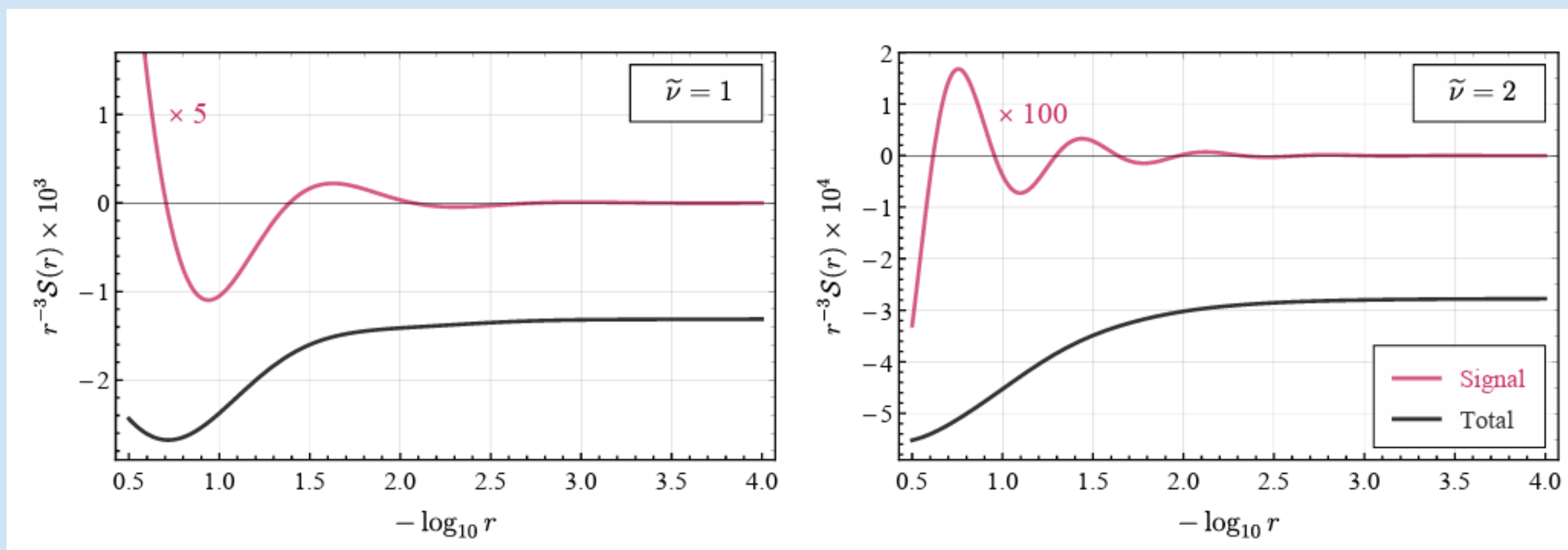

Figure 3 The 1-loop 3pt correlator with mass parameter $\tilde\nu$.

4. Consistency check:

a) Correct UV divergence: We perform the calculation in general (d+1)-dim to implement dim. reg. and MS-bar. The UV divergence is manifestly local and is identical to flat space result.

b) Large mass limit: We check that the limit of large intermediate mass also reduces to flat-space result.

c) Squeezed limit: The full expression matches a direct integration in the sqeezed limit.

d) No spurious poles in the folded limit by construction.

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