CROSS-CORRELATION OF METRIC AND MONOPOLE PERTURBATIONS FROM HOLOGRAPHIC COSMOLOGY

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ABSTRACT

We aim to investigate cosmological non-Gaussianities associated with the magnetic monopole field and metric perturbations. Using the phenomenological approach of holographic cosmology, we map the correlators of a 3D QFT into a cosmological theory. The main expected result is the derivation of the cross-correlation between metric perturbations (scalar and tensor) and the magnetic monopole field in the squeezed limit, where one mode has a much smaller momentum than the others. This is achieved through the 1-loop calculation of the $\langle TJJ \rangle$ correlator of the dual QFT.

INTRODUCTION

Holographic cosmology maps primordial observables to 3D QFT correlators, establishing a precise dictionary between cosmological spacetimes and boundary Quantum Field Theories. The two-point functions determine the power spectra of metric and monopole fields; within this framework, the monopole problem is naturally resolved by identifying the dual vortex current as a relevant operator.

One can go beyond the Gaussian statistics captured by 2-point functions and compute higher-order correlations, specifically the bispectra which encode primordial non-Gaussianities. In this work, we compute the 1-loop $\langle TJJ \rangle$ correlator, which maps to the mixed bispectra of scalar/tensor perturbations and the monopole field. Our focus is on the squeezed limit $(p_1 \to 0)$, where we extract the effective non-linearity parameters f_{NL} governing these cross-correlations quantifying the modulation of the monopole power spectrum by long-wavelength metric modes.

OBJECTIVE

Our goal is to calculate the 3-point function $\langle T_{\mu\nu} J^a_\rho J^b_\sigma \rangle$ in a 3D QFT (a toy model with SO(3) symmetry), and apply the holographic map to extract the non-Gaussianities of the cosmological correlators $\langle \xi AA \rangle$ and $\langle \gamma AA \rangle$. We aim to derive the effective non-linearity parameters f_{NL} for these cross-correlations in the squeezed limit.

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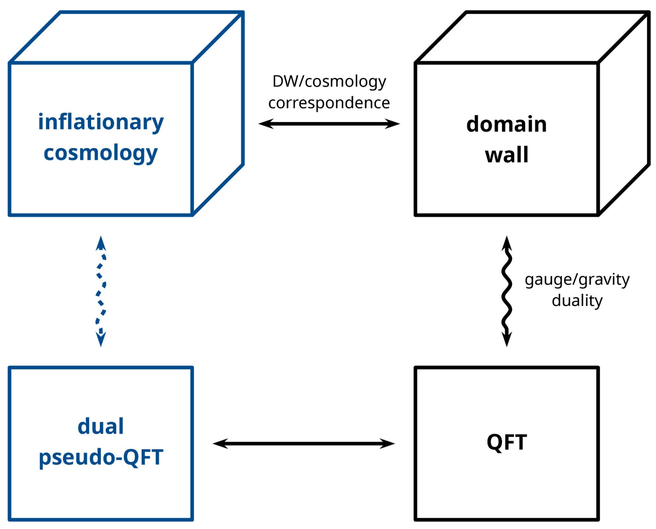
[2] After angular averaging.

METHODOLOGY



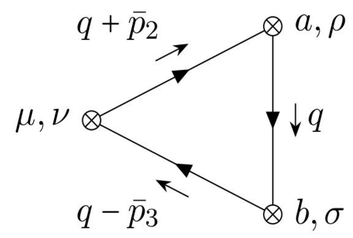
The Holographic Map:
Cosmological variables are mapped to gauge-invariant operators of the QFT:

$$\xi(p) \leftrightarrow T(p) \qquad \gamma_{\mu\nu}(p) \leftrightarrow \frac{1}{4} T^{TT}_{\mu\nu}(p)$$

$$\tilde{A}^a_\mu(p) \leftrightarrow \tilde{J}^a_\mu(p)$$

where TT is the trace of the energy-momentum tensor, TT is its transverse-traceless part, and J is the magnetic vortex current.

Calculation of the TJJ Correlator: The 1-loop triangle diagram of the TJJ correlator in the squeezed limit $(p_1 \to 0, p_2 \simeq -p_3 = p)$is calculated as:



$$\langle T_{\mu\nu}(0) J^a_\rho(\bar{p}) J^b_\sigma(-\bar{p}) \rangle = \delta_{\mu\nu} \langle J^a_\rho(\bar{p}) J^b_\sigma(-\bar{p}) \rangle - \delta_{\mu\sigma} \langle J^a_\rho(\bar{p}) J^b_\nu(-\bar{p}) \rangle$$
$$- \delta_{\mu\rho} \langle J^a_\sigma(\bar{p}) J^b_\nu(-\bar{p}) \rangle - \bar{p}_\nu \frac{\partial}{\partial \bar{p}^\mu} \langle J^a_\rho(\bar{p}) J^b_\sigma(-\bar{p}) \rangle + \mathcal{O}(\epsilon)$$

Cosmological Results: Applying the holographic map and taking the squeezed limit, the correlations factor into power spectra and a factor known as the "running scaling" (the logarithmic derivative of the monopole power spectrum).

- For the scalar perturbation:

$$\langle \xi(0) \tilde{A}^a_\rho(p) \tilde{A}^b_\sigma(-p) \rangle = \delta^{ab} \left(1 + p \frac{\mathcal{P}'_{\tilde{A}}(p)}{\mathcal{P}_{\tilde{A}}(p)} \right) \pi_{\rho\sigma}(p) \mathcal{P}_\xi(0) \mathcal{P}_{\tilde{A}}(p)$$

- For the tensor perturbation[2]:

$$\langle \gamma_{\mu\nu}(0) \tilde{A}^{a\mu}(p) \tilde{A}^{b\nu}(-p) \rangle = -\frac{\delta^{ab}}{15} \left(7 + p \frac{\mathcal{P}'_{\tilde{A}}(p)}{\mathcal{P}_{\tilde{A}}(p)} \right) \mathcal{P}_\gamma(0) \mathcal{P}_{\tilde{A}}(p)$$

MAIN RESULTS

We define the effective nonlinearity parameters f_NL for the cross-correlations with the monopole:

For the scalar-monopole correlation (ξAA): We find $f_{NL}^{\xi\tilde{A}\tilde{A}} = 1 + p \frac{\mathcal{P}'_{\tilde{A}}(p)}{\mathcal{P}_{\tilde{A}}(p)}$. Surprisingly, at 1-loop order, $f_{NL}^{\xi\tilde{A}\tilde{A}} = 0$. This implies that a background scalar perturbation does not induce any deviation from the Gaussian distribution of the monopole fields at the leading order.

For the tensor-monopole correlation (γAA): We define $f_{NL}^{\gamma\tilde{A}\tilde{A}} = 7 + p \frac{\mathcal{P}'_{\tilde{A}}(p)}{\mathcal{P}_{\tilde{A}}(p)}$. Applying our 1-loop holographic results, we obtain $f_{NL}^{\gamma\tilde{A}\tilde{A}} = 6$.

This establishes a clear hierarchy of non-Gaussian amplitudes: $\langle \xi\xi\xi \rangle > \langle \xi\tilde{A}\tilde{A} \rangle > \langle \gamma\tilde{A}\tilde{A} \rangle$.

REFERENCES

[1] Maldacena, J. "Non-gaussian features of primordial fluctuations in single field inflationary models." JHEP 05, 013 (2003).
[2] McFadden, P., & Skenderis, K. "Holography for Cosmology." Phys. Rev. D 81, 021301 (2010).
[3] Nastase, H. "Holographic cosmology solutions of problems with pre-inflationary cosmology." JHEP 12, 026 (2020).
[4] Bzowski, A., McFadden, P., & Skenderis, K. "Holographic predictions for cosmological 3-point functions." JHEP 03, 091 (2012).
[5] Cravo, M., & Nastase, H. "3-point function of currents for holographic cosmology and monopole non-Gaussianities." JHEP 05, 056 (2024).

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