Cosmo Correlators in Taiwan @ LeCosPA
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The Best-Fit Cosmological Collider

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Based on [2404.05031]

LPTHE
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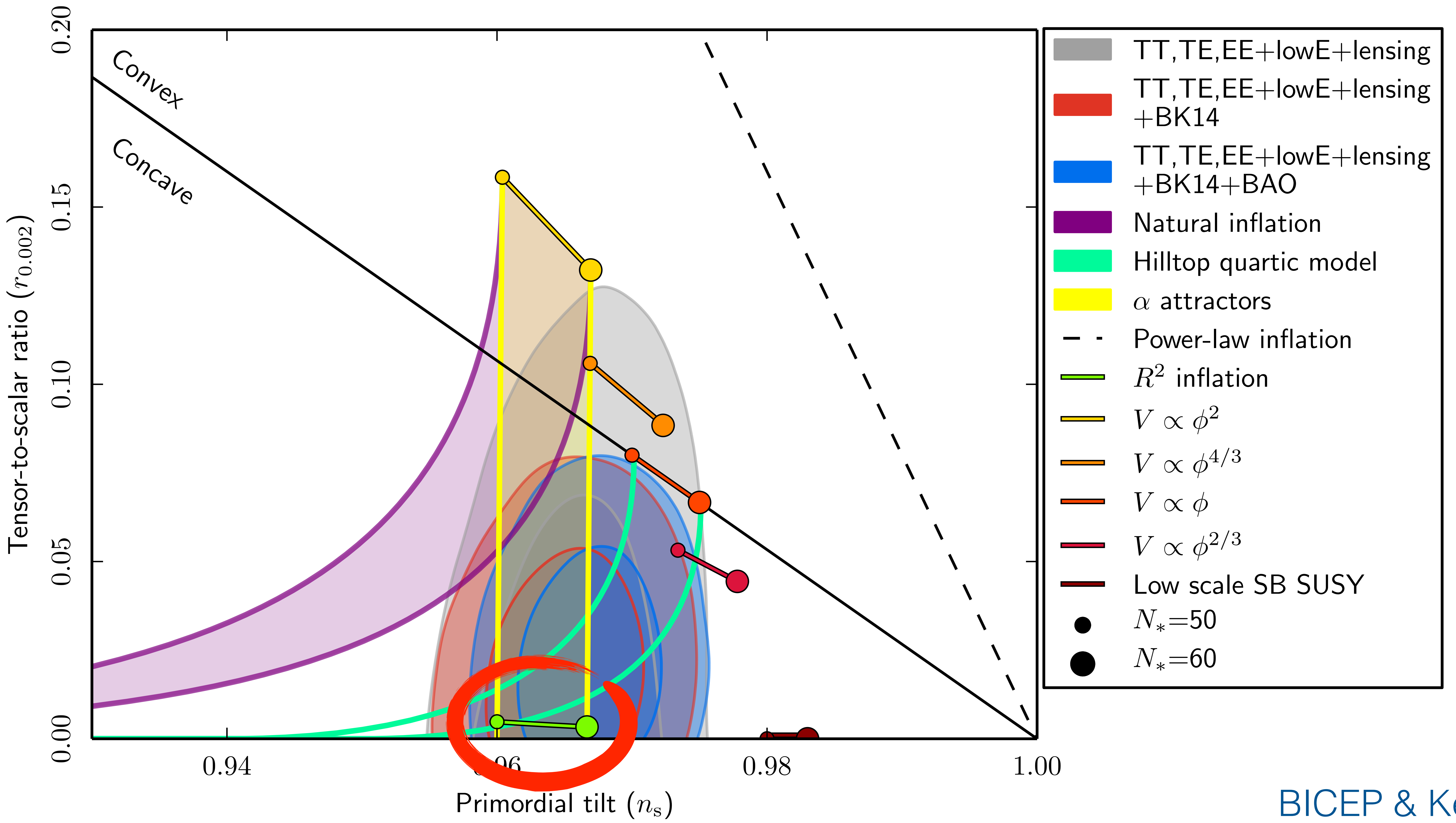
Single-field slow-roll inflation in Einstein gravity



BICEP & Keck (2021)

PLANCK (2018)

$$n_s = 0.9649 \pm 0.0042 \quad (1\sigma)$$

$$r < 0.036$$

R^2 inflation

Starobinsky (1980, 1984)

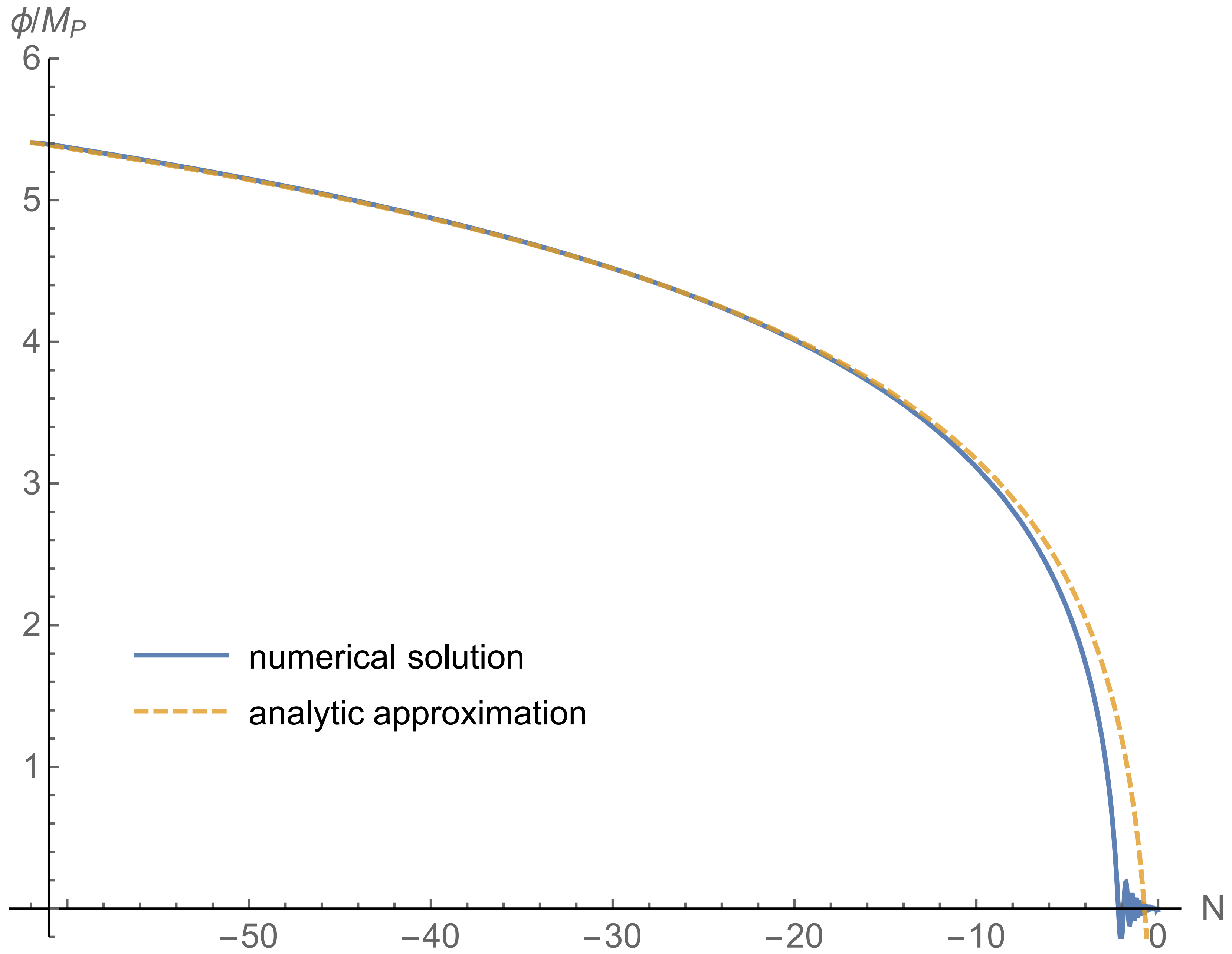
- (one of) the first, the most elegant (one-parameter) and the best-fit

[Maggiore 2018]

$$S = \int d^4x\sqrt{-g_J}\,\frac{M_P^2}{2}\left[R_J + \frac{R_J^2}{6M^2}\right]$$
$$= \int d^4x\sqrt{-g_E}\left[\frac{M_P^2}{2}R_E - \frac{1}{2}(\partial\phi)_E^2 - U(\phi)\right]$$

$$g^J_{\mu\nu} = e^{-\sqrt{\frac{2}{3}}\frac{\phi}{M_P}}\,g^E_{\mu\nu}$$

$\phi \equiv$ scalaron



Large-Field Inflation and the Cosmological Collider

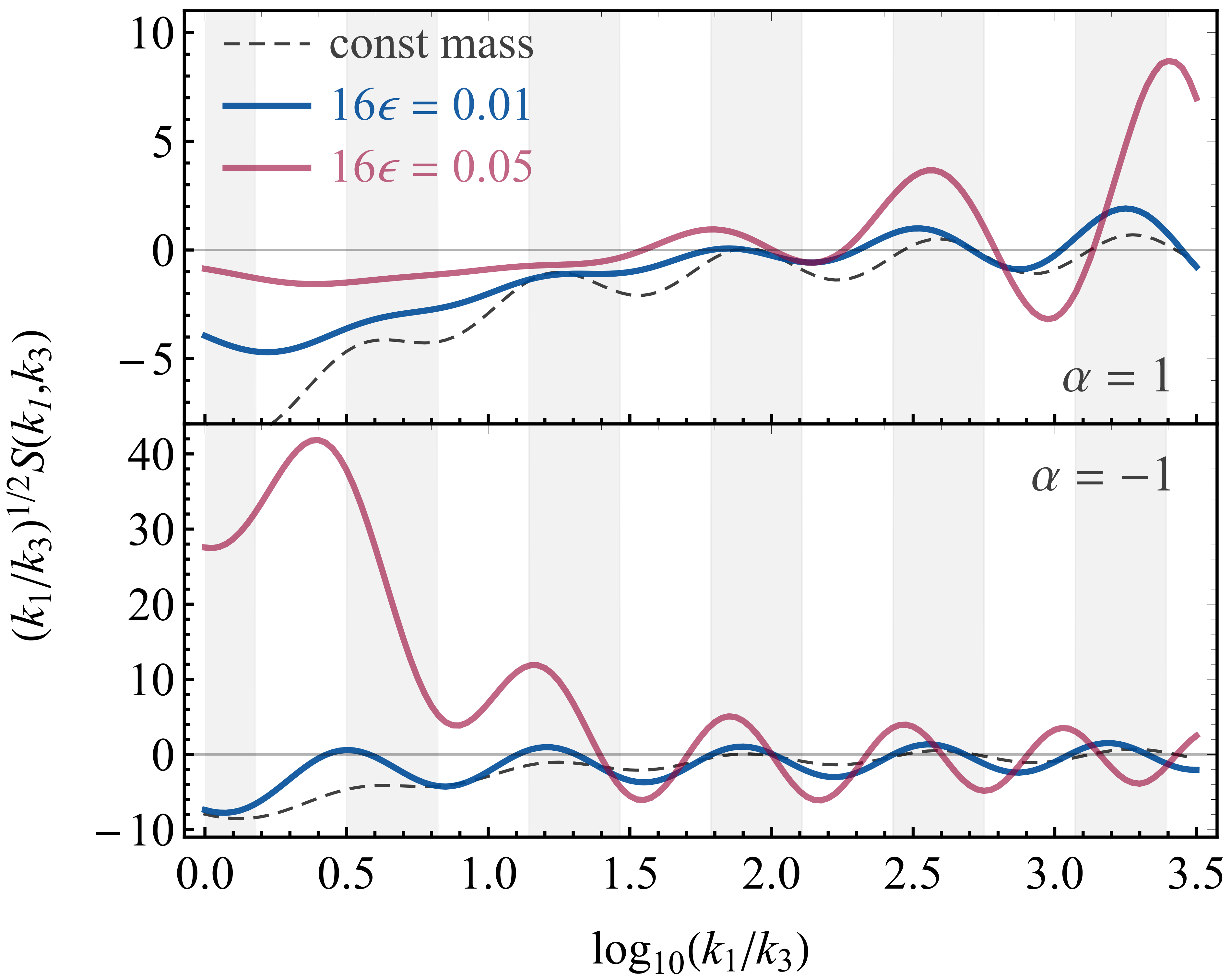
[2204.11869]

Matthew Reece, Lian-Tao Wang, Zhong-Zhi Xianyu

large field : $\Delta\phi/M_P > 1$

swampland distance conjecture : $\sim e^{-\alpha\phi/M_P}$

time-varying mass : $m^2(t) = e^{-\alpha\phi(t)/M_P} m_\sigma^2$



R^2 inflation

Starobinsky (1980, 1984)

$$g^J_{\mu\nu} = e^{-\sqrt{\frac{2}{3}}\frac{\phi}{M_P}} g^E_{\mu\nu}$$

$$\phi \equiv \text{scalaron}$$

$$S = \int d^4x\sqrt{-g_J}\,\frac{M_P^2}{2}\left[R_J + \frac{R_J^2}{6M^2}\right] + \int d^4x\sqrt{-g_J}\,\mathcal{L}_{\text{matter}},$$

$$= \int d^4x\sqrt{-g_E}\left[\frac{M_P^2}{2}R_E - \frac{1}{2}(\partial\phi)^2_E - U(\phi)\right] + \int d^4x\sqrt{-g_E}\,\underline{\underline{e^{-2\sqrt{\frac{2}{3}}\frac{\phi}{M_P}}}}\,\mathcal{L}_{\text{matter}},$$

large field : $\Delta\phi/M_P > 1$

conformal coupling with scalaron : $\sim e^{-\alpha\phi/M_P}, \qquad \alpha = \sqrt{2/3}$

time-varying mass : $m^2(t) = e^{-\alpha\phi(t)/M_P} m_\sigma^2$

The cosmological collider in R^2 inflation

YPW [2404.05031]

analytic inflaton + numerical massive scalar

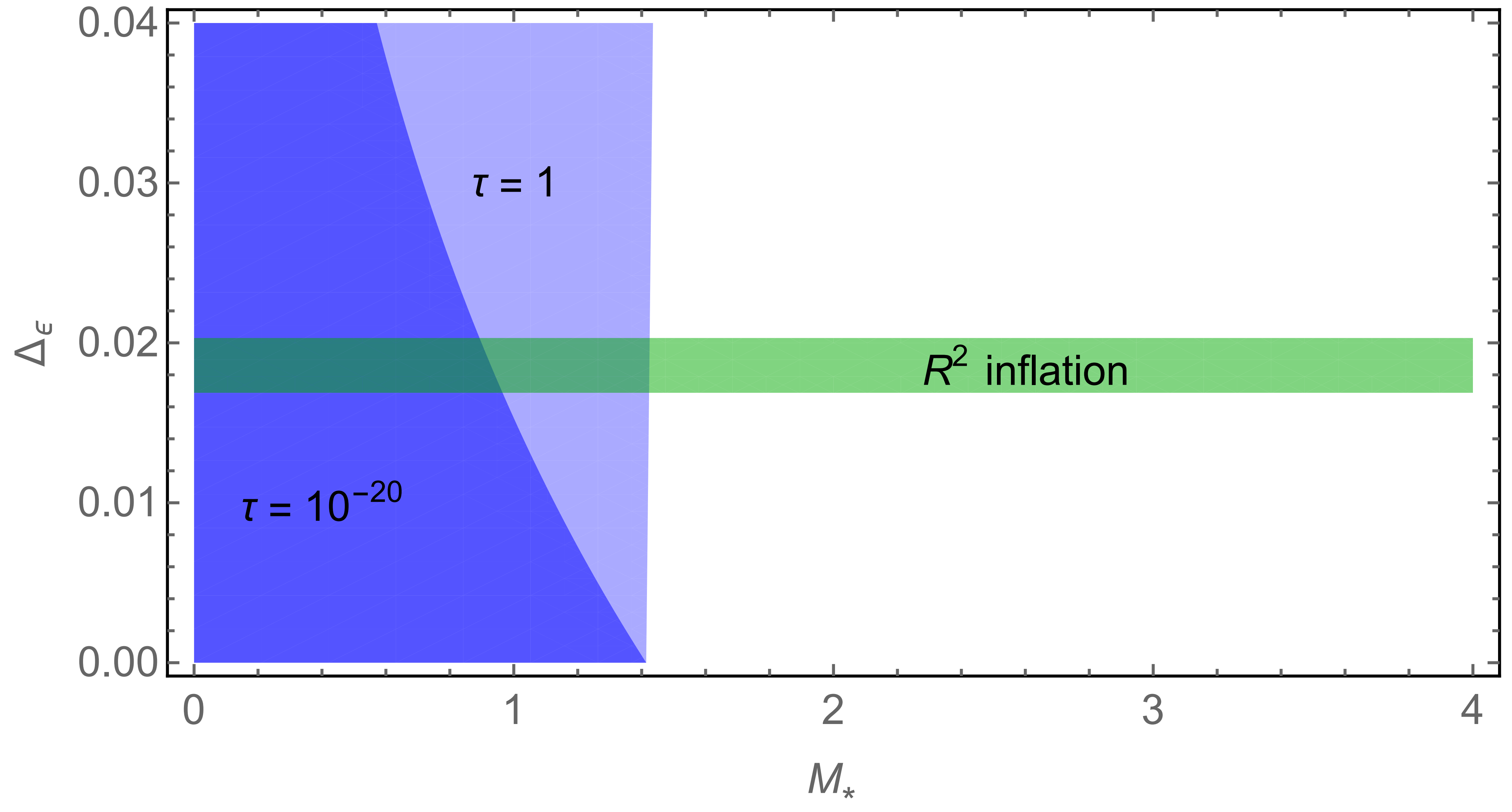
$$\ddot{\delta\sigma} + \left(3 - \sqrt{\frac{2}{3}}\frac{\dot{\phi}_0}{M_P H}\right) H\dot{\delta\sigma} + \left(\frac{k^2}{a^2} + e^{-\sqrt{\frac{2}{3}}\frac{\phi_0}{M_P}} V_{\sigma\sigma}\right)\delta\sigma = 0,$$

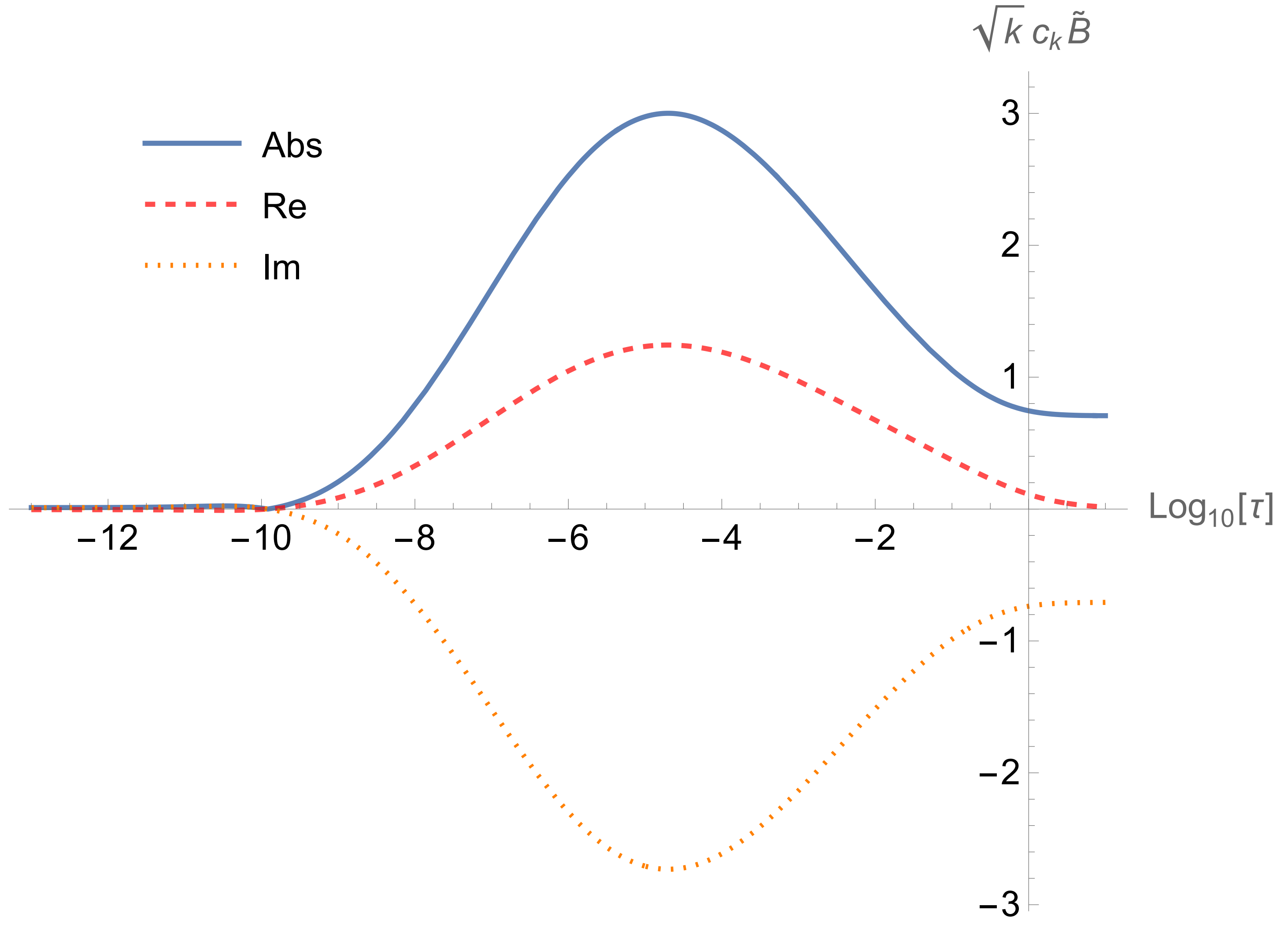
$$\frac{\partial^2}{\partial\tau^2}\tilde{u}_k + \left[1 - \left(1 + \frac{\Delta_\epsilon}{2}\right)\left(2 + \frac{\Delta_\epsilon}{2}\right)\frac{1}{\tau^2} + \frac{M_*^2}{\tau^{2+\Delta_\epsilon}}\left(\frac{k}{k_*}\right)^{\Delta_\epsilon}\right]\tilde{u}_k = 0,$$

$$\tilde{u}_k(\tau) = c_k(\nu)\tilde{B}(\tau)e^{i\tau}, \qquad c_k(\nu) = -\frac{i}{2}\sqrt{\frac{\pi}{k}}e^{i(\nu+1/2)\pi/2},$$

The cosmological collider in R^2 inflation

YPW [2404.05031]

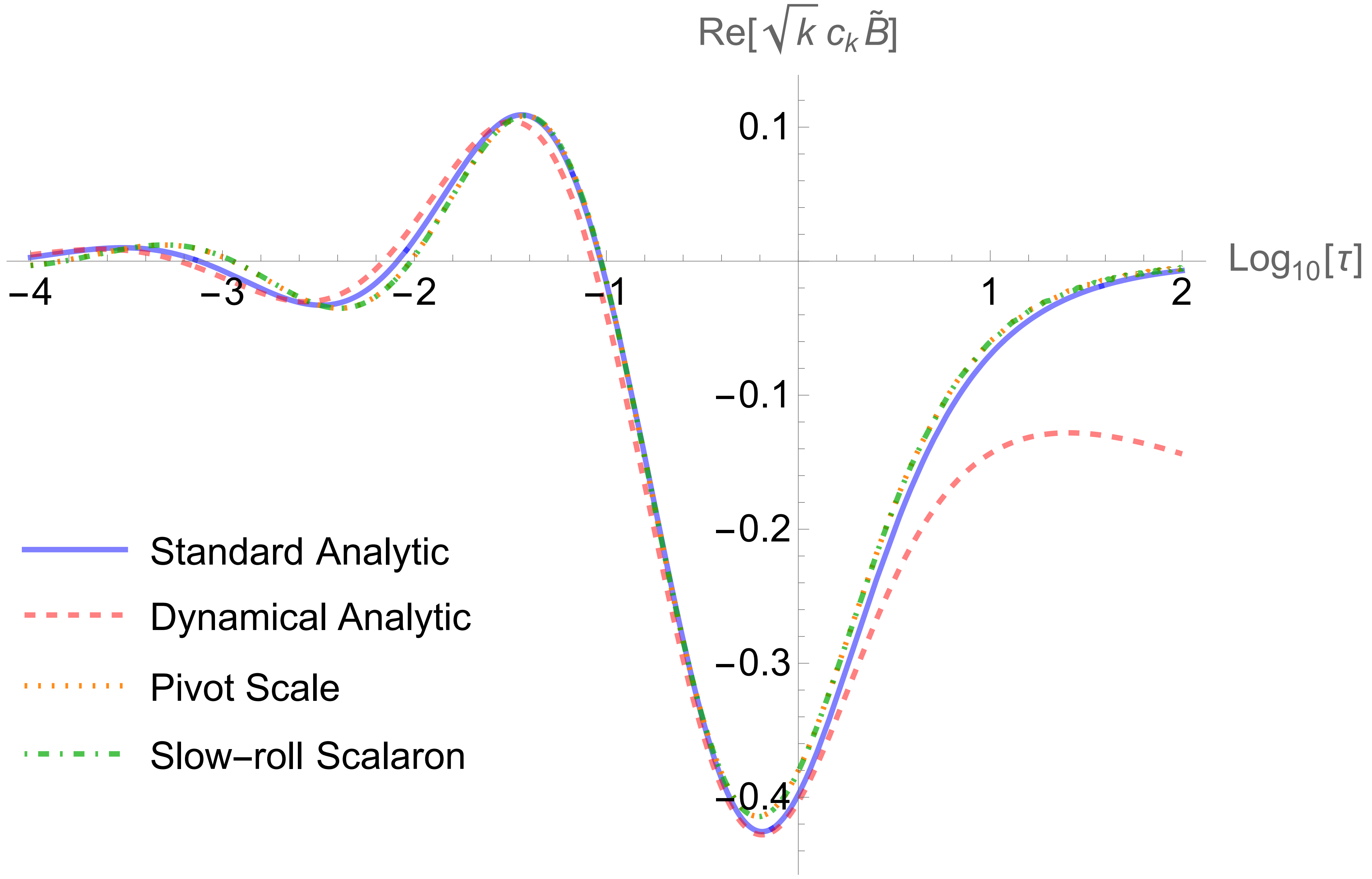




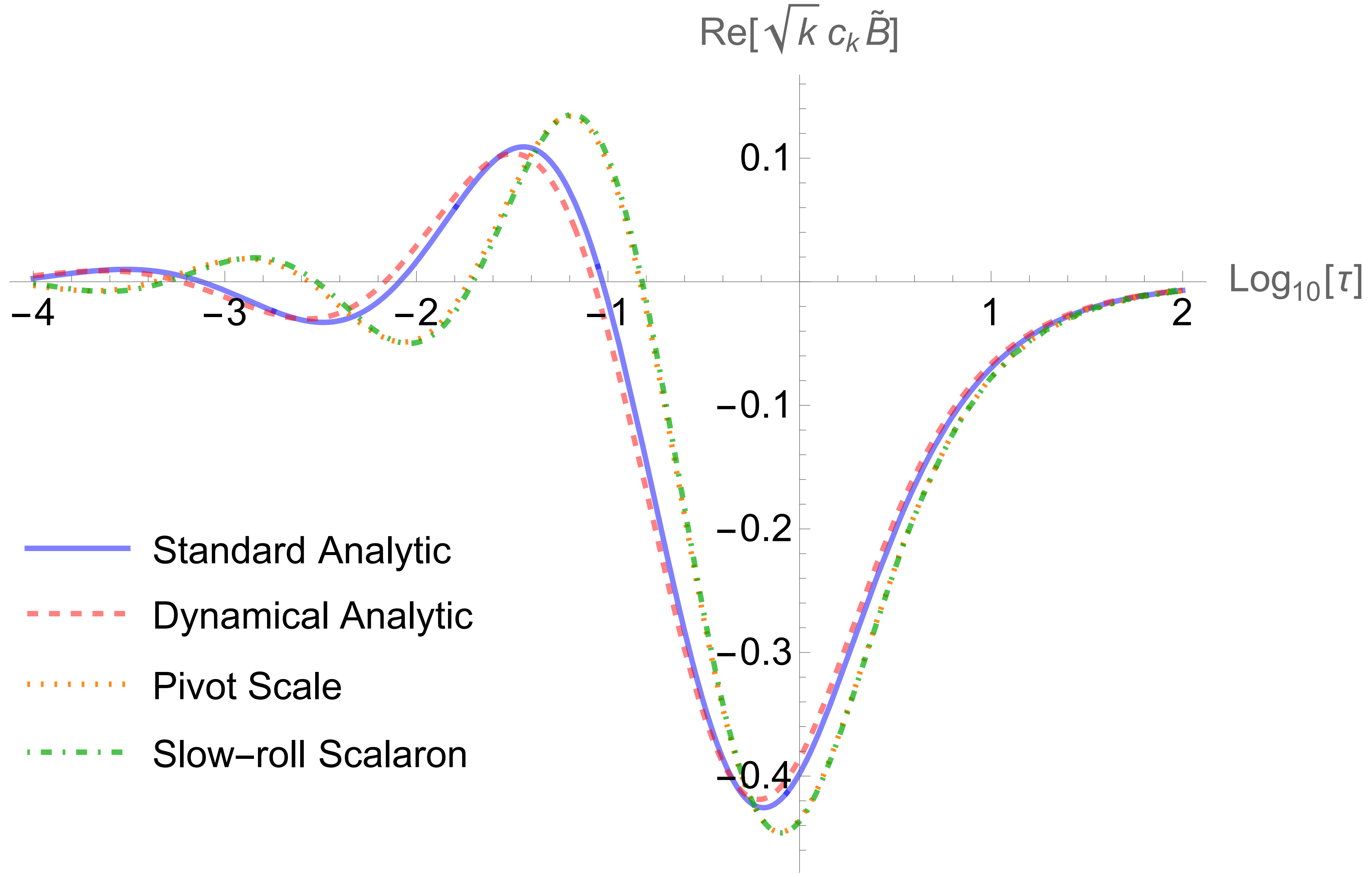
See also the cosmological tachyon collider: McCulloch, Pajer & Tong [2401.11009]

Factorized mode functions

Dynamical Analytic: Aoki, Noumi, Sano & Yamaguchi [2312.09642]
Pivot Scale: Reece, Wang & Xianyu [2204.11869]
Slow-roll Scalaron: YPW [2404.05031]



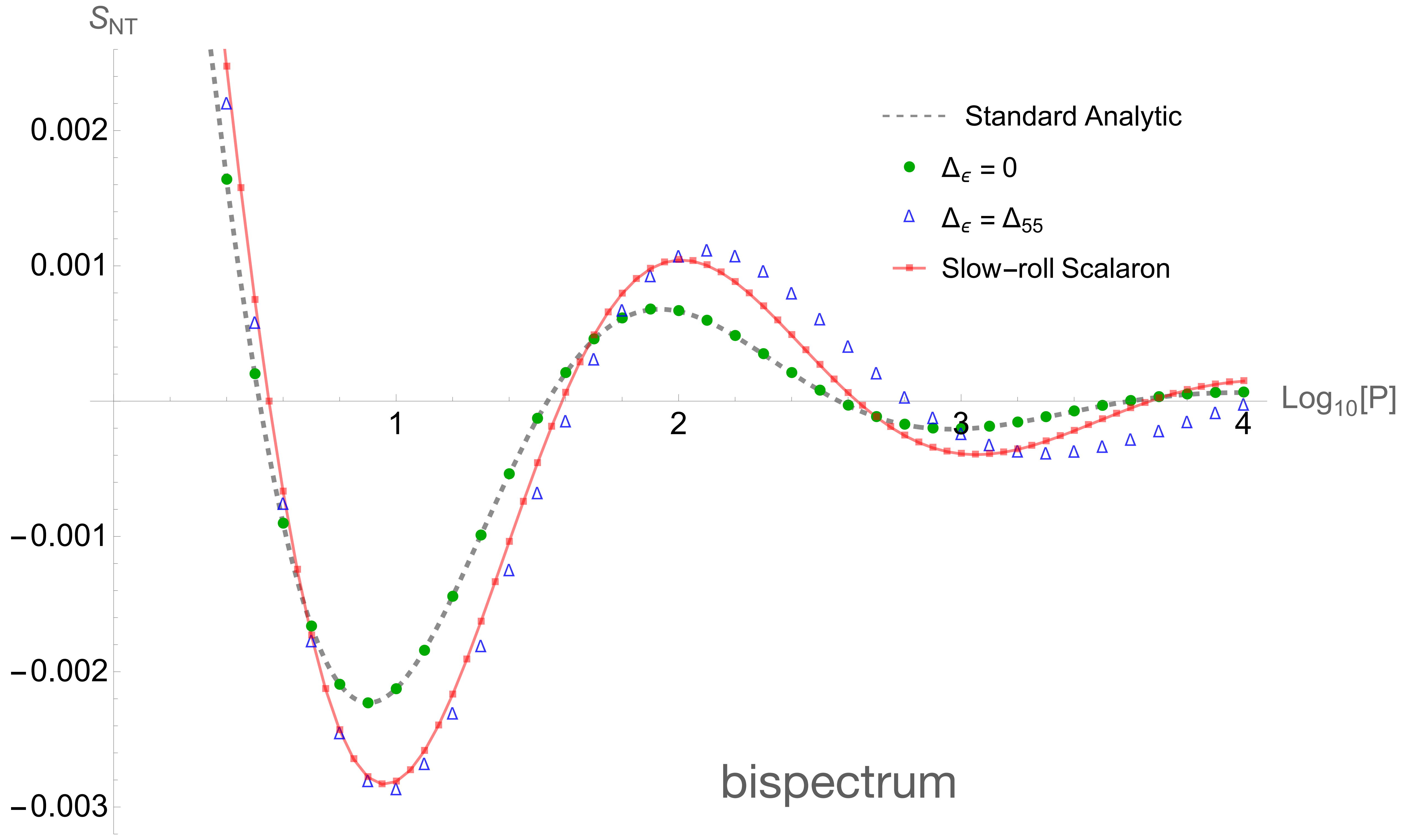
$k/k_* = 1$



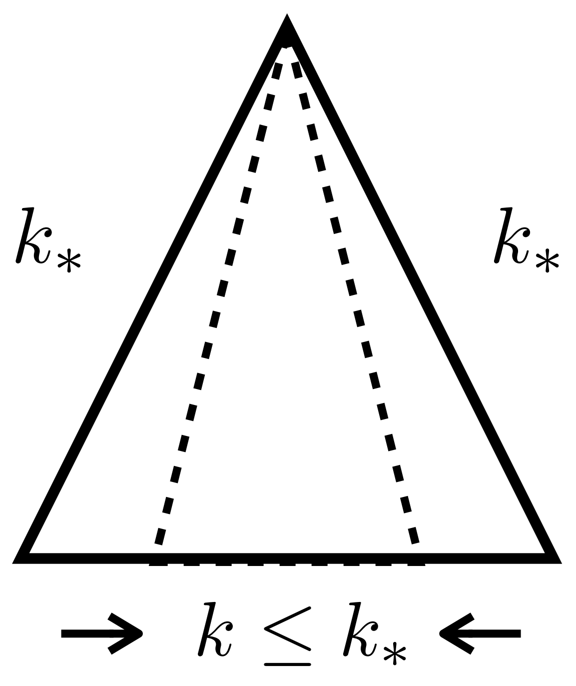
$k/k_* = 1000$

Bispectrum

YPW [2404.05031]

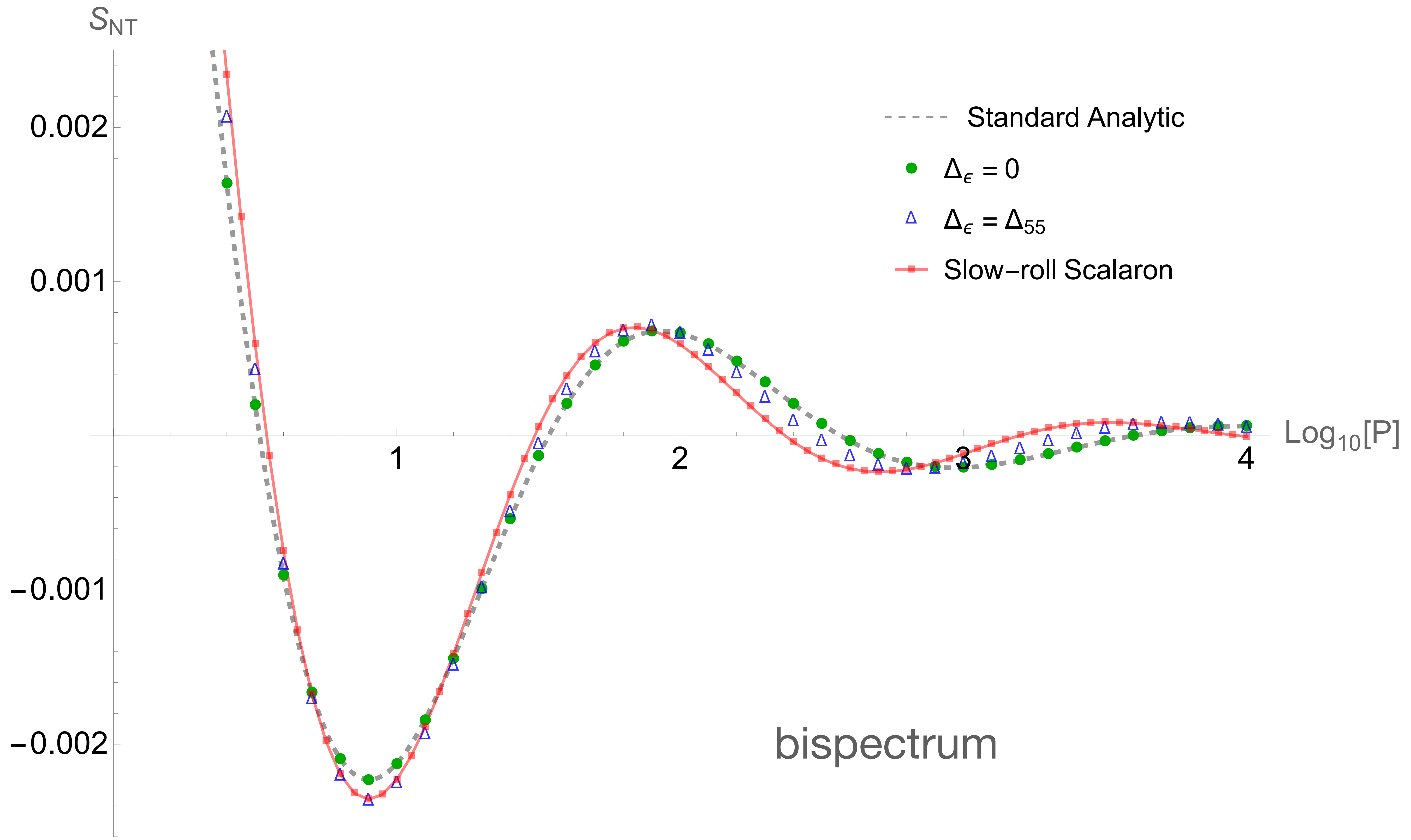


$$P = \frac{2k_*}{k}$$

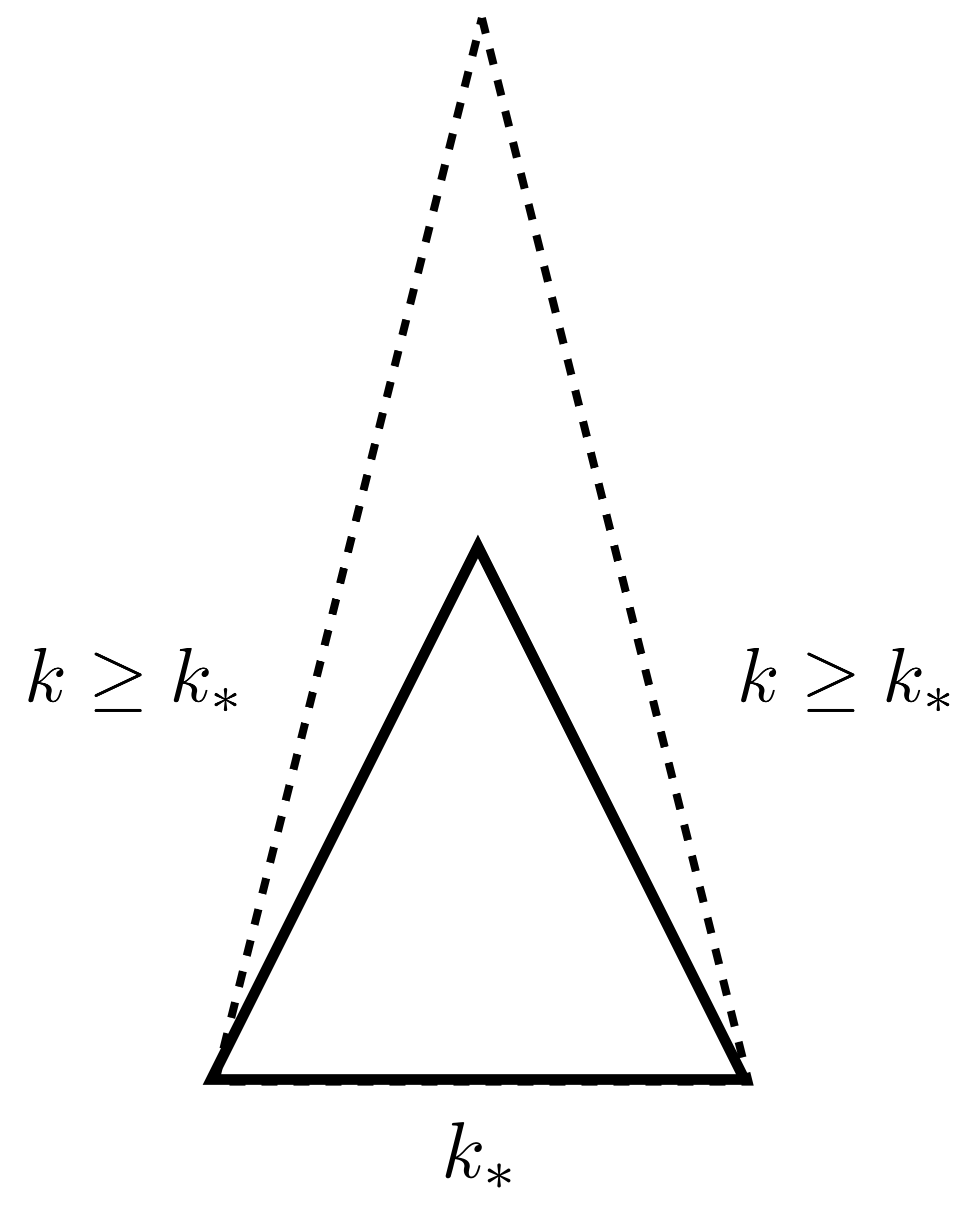


Bispectrum

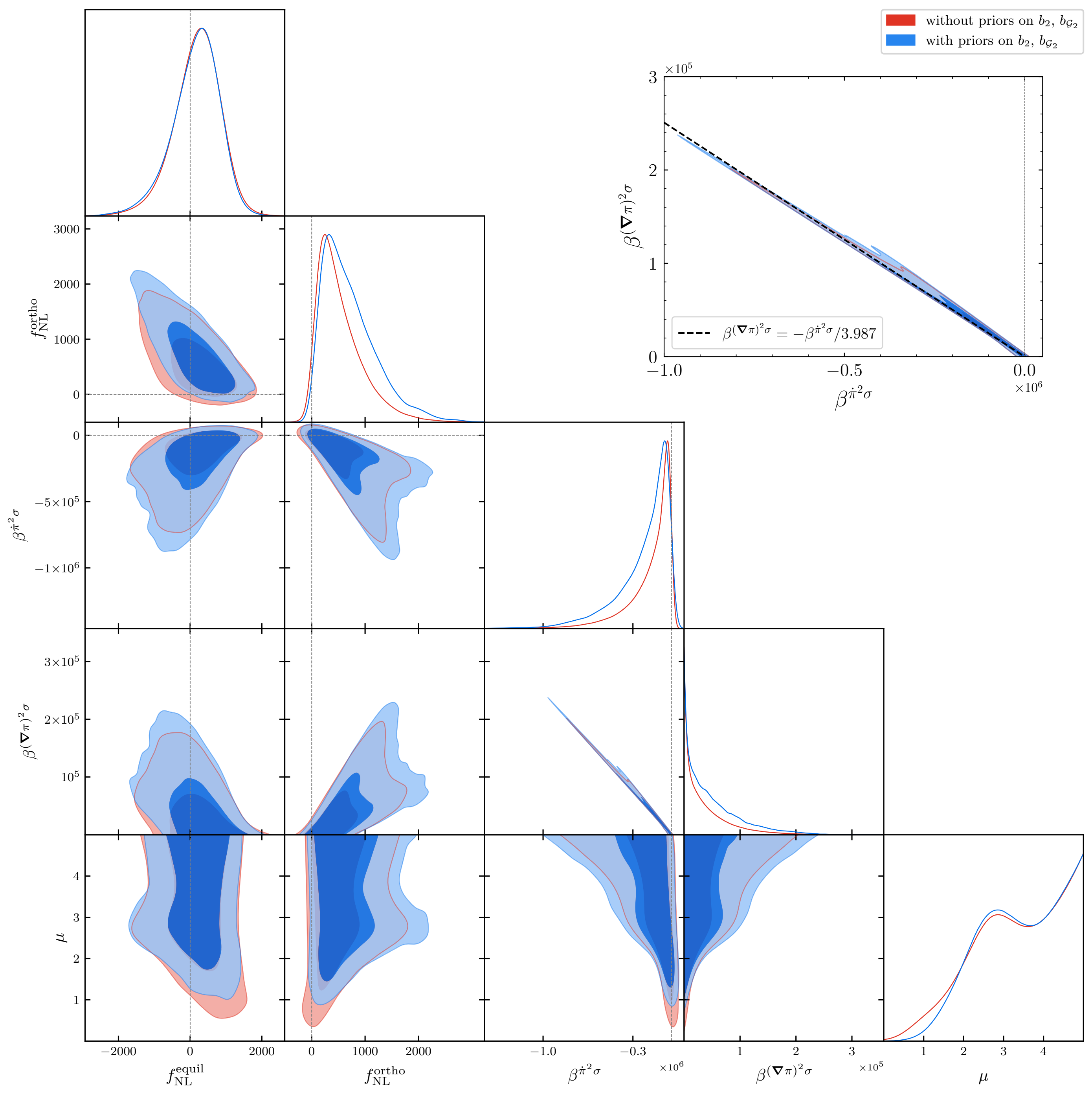
YPW [2404.05031]



$$P = \frac{2k}{k_*}$$



The Cosmological Collider — is in action since 2024 !!

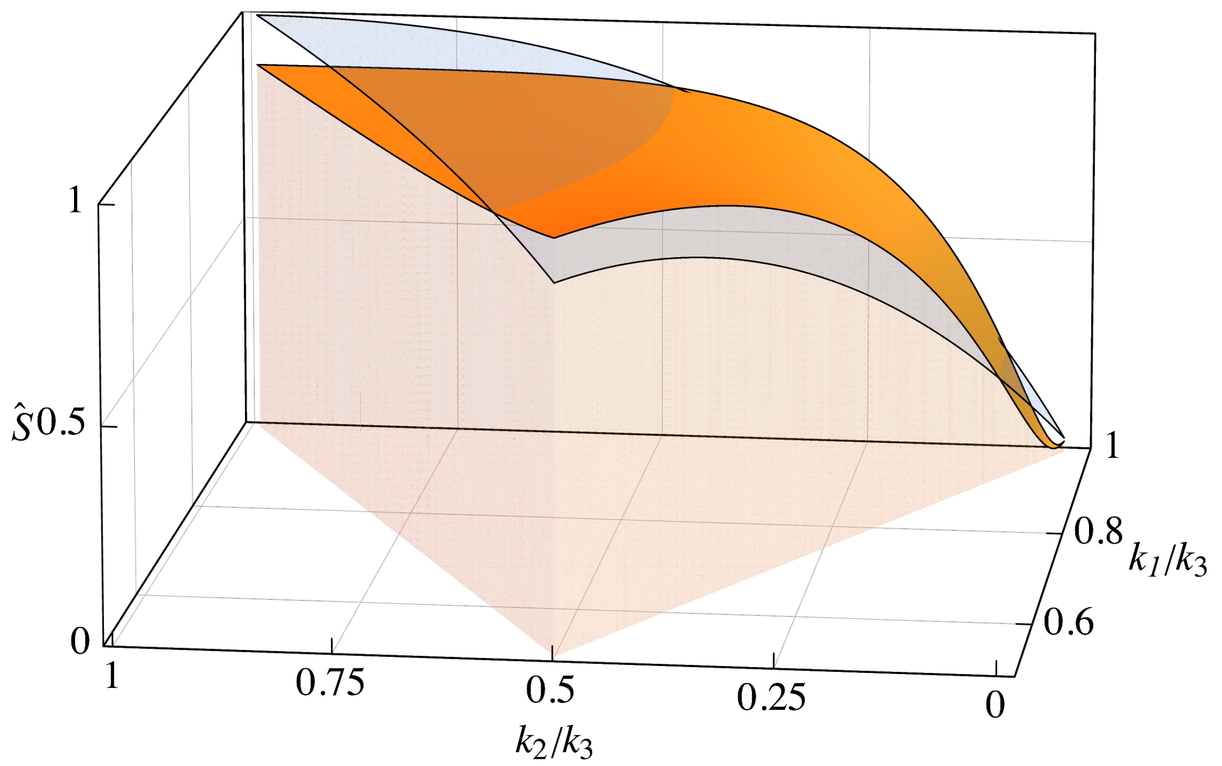


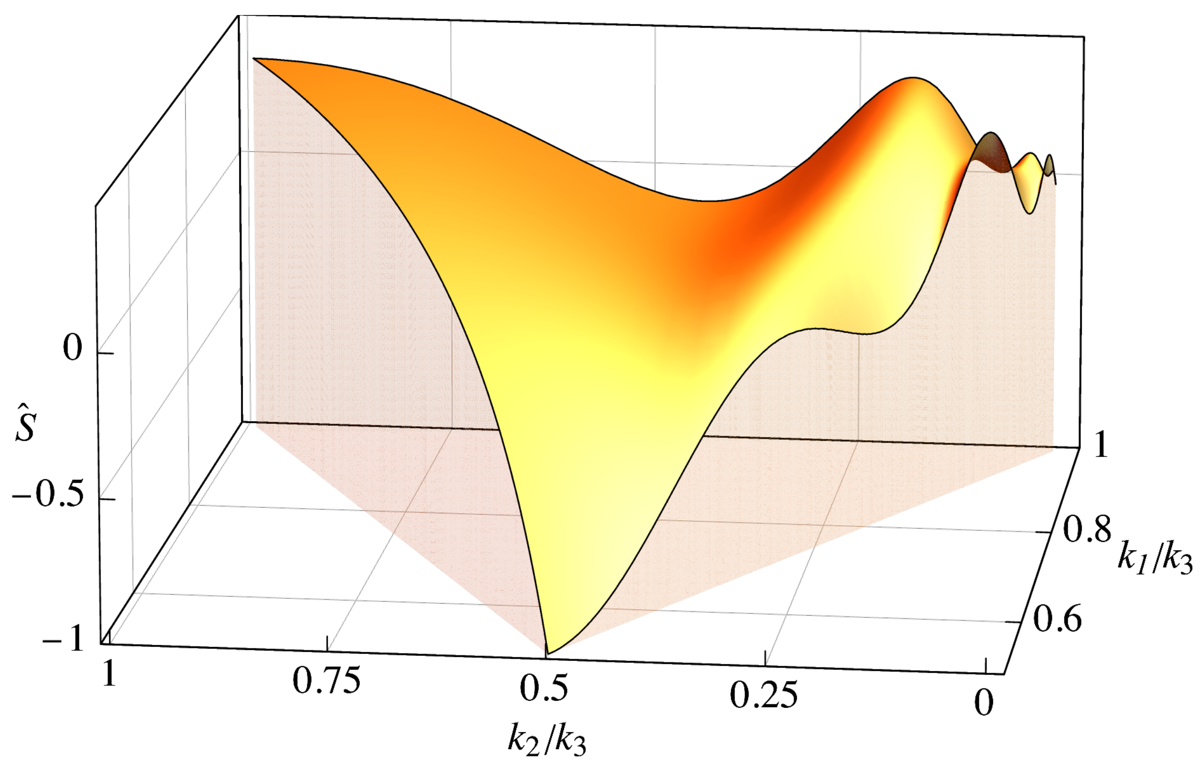
A first report from Baryon Oscillation Spectroscopic Survey (BOSS):

Cabass, et.al. [2404.01894]

	without galaxy-formation priors			including galaxy-formation priors		
Parameter	mean	95% lower	95% upper	mean	95% lower	95% upper
$f_{\rm NL}^{\rm equil}$	1.9×10^2	-1.2×10^3	1.4×10^3	1.5×10^2	-1.2×10^3	1.4×10^3
$f_{\rm NL}^{\rm ortho}$	5.4×10^2	-1.2×10^2	1.5×10^3	7.1×10^2	-6.6×10^1	1.8×10^3
$\beta^{\dot\pi^2\sigma}$	-1.6×10^5	-5.4×10^5	3.7×10^4	-2.0×10^5	-6.6×10^5	4.9×10^4
$\beta^{(\boldsymbol{\nabla}\pi)^2\sigma}$	–	–	$< 1.3\times10^5$	–	–	$< 1.6\times10^5$
μ	–	> 1.4	–	–	> 1.7	–

The Cosmological Collider — is in action since 2024 !!





A first report from Planck CMB data:

Sohn, Wang, Fergusson & Shellard [2404.07203]

Shape	Template	f_{NL} (68% CL)	Raw S/N	Adjusted S/N
Light scalar exchange [3]	(2.6)	10 ± 26	0.37	0.12
Scalar exchange I	(2.15)	11 ± 13	0.86	0.67
Scalar exchange II	(2.20)	-91 ± 40	2.3	1.8
Heavy-spin exchange	(2.24)	-59 ± 32	1.9	1.2
Massive spin-2 exchange	(2.27)	-2.1 ± 1.1	1.9	0.90
Equilateral collider [61]	(2.32)	-178 ± 72	2.5	0.90
Low-speed collider [42]	(2.33)	-9 ± 10	0.89	0.29
Multi-speed PNG [66]	(2.34)	-3.1 ± 2.3	1.3	0.61

Applications:

$$(1)\ \ f(R)\ \text{gravity} \to e^{-\alpha\phi/M_P},\ \alpha = \sqrt{2/3}$$

$$(2)\ \ \text{Higgs inflation} \sim h^2\sigma^2 \sim \frac{M_P^2}{\xi} e^{\alpha\phi/M_P}\sigma^2$$

$$(3)\ \ \text{The Standard Model mass spectrum.}$$

Chen, Wang & Xianyu (2017a,b)

Thank you very much!

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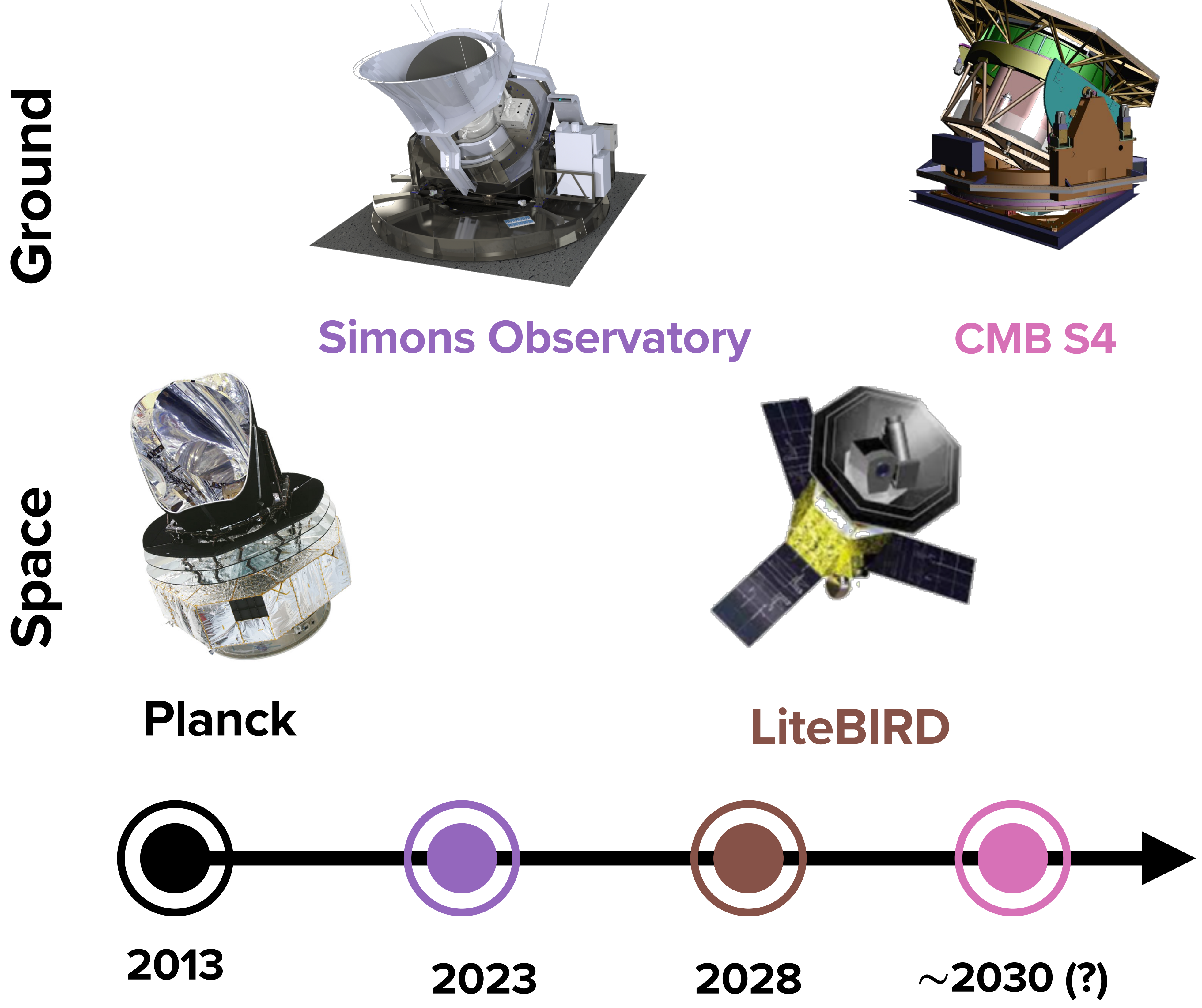
Future CMB experiments timeline

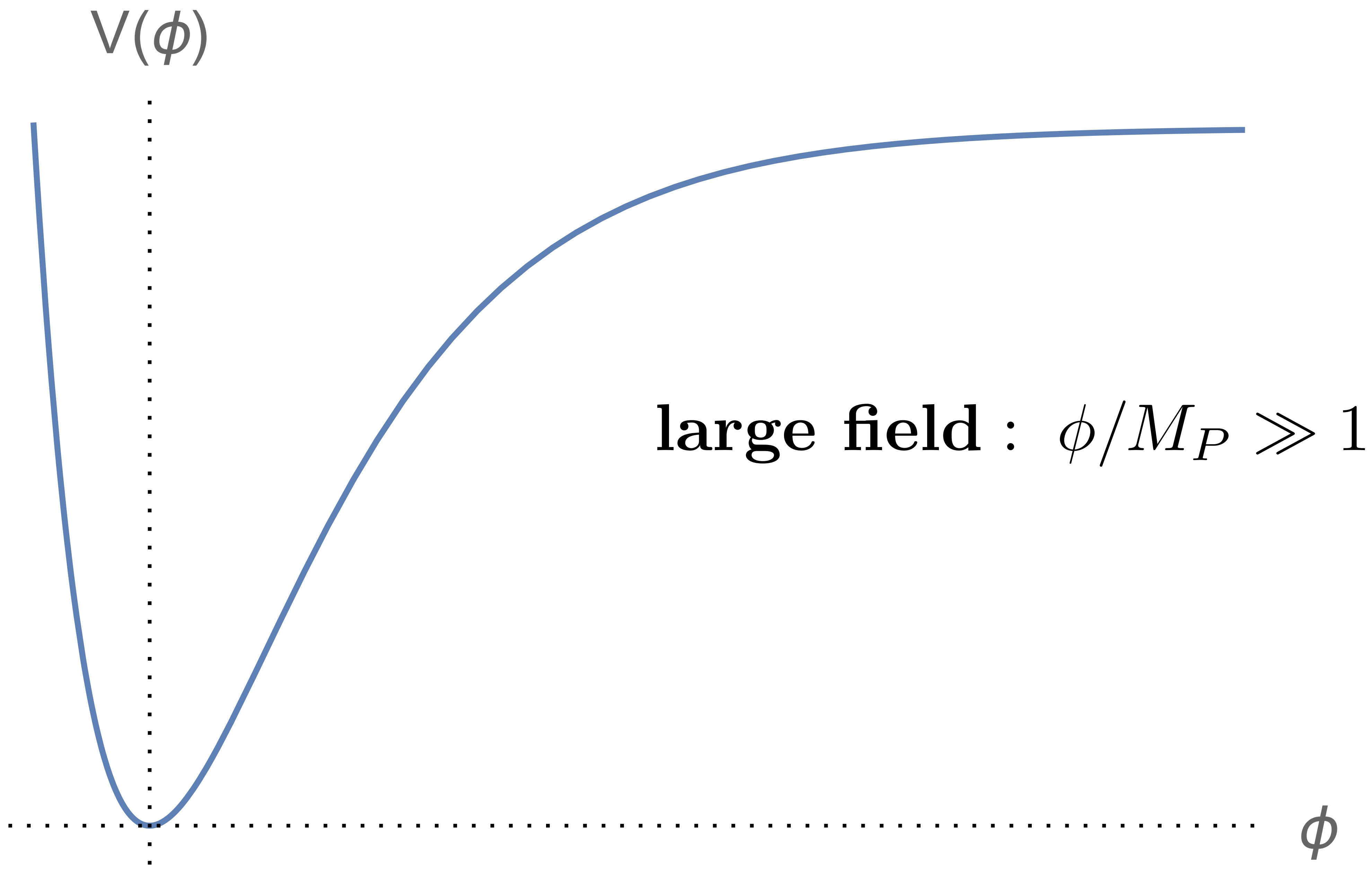
Braglia, Chen, Hazra & Pinol [2210.07028]



$r < 0.01 \ (?)$

R^2 inflation

Starobinsky (1980, 1984)



large field : $\phi/M_P \gg 1$

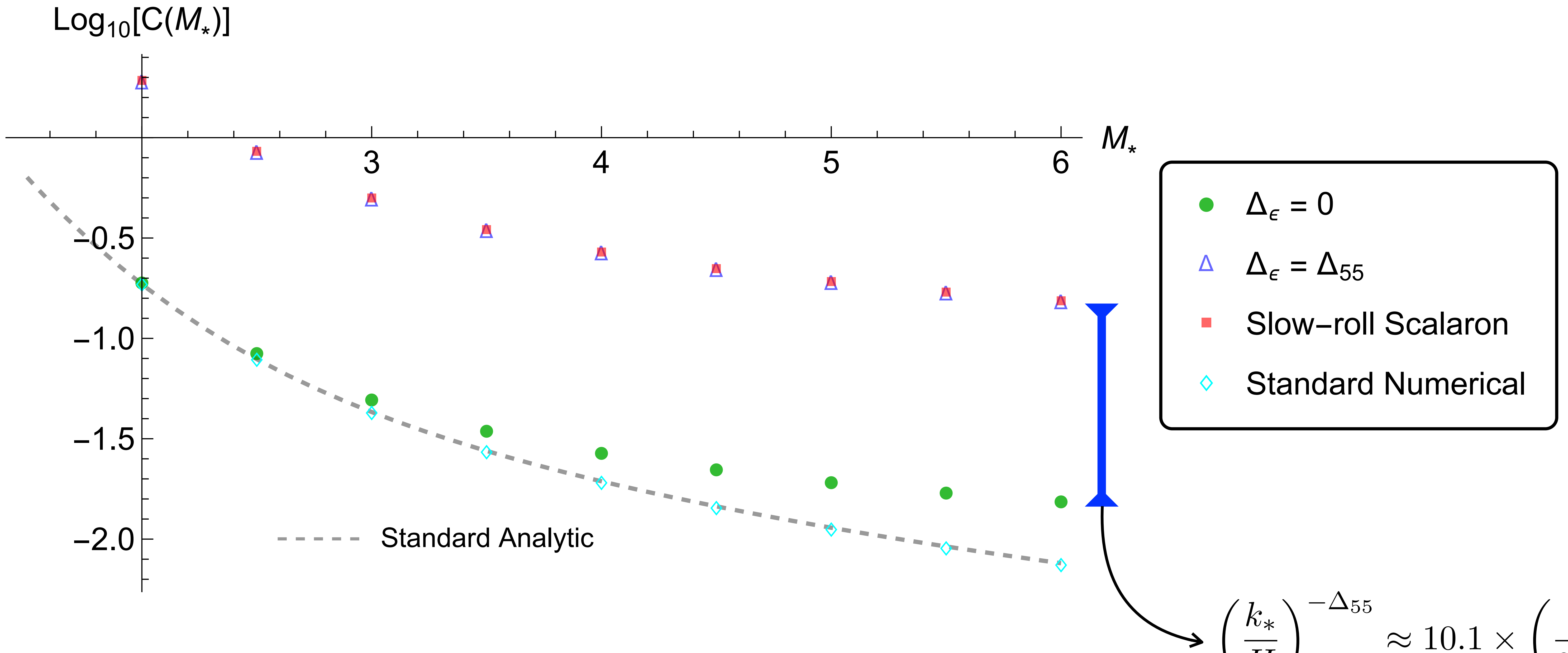
$$U(\phi) = \frac{3}{4}M_P^2 M^2 \left(1 - e^{-\sqrt{\frac{2}{3}}\frac{\phi}{M_P}}\right)^2$$

$$n_s - 1 \simeq -0.036 \times \frac{55}{\Delta N_*}$$

$$r \simeq 4.0 \times 10^{-3} \times \left(\frac{55}{\Delta N_*}\right)^2$$

Power spectrum

YPW [2404.05031]



$$\left(\frac{k_*}{H}\right)^{-\Delta_{55}} \approx 10.1 \times \left(\frac{k_*}{0.002\ \mathrm{Mpc}^{-1}} \frac{3\times 10^{13}\ \mathrm{GeV}}{H}\right)^{-\Delta_{55}}$$

power spectrum $$\frac{\Delta P}{P_0} \sim \beta_{\mathrm{model}} \times C(\Delta_\epsilon, M_*, k/k_*),$$