SISSA
Lorenzo Bordin (Trieste)

SAPIENZA
UNIVERSITÀ DI ROMA
Giovanni Cabass (Rome)

# Simplifying the EFT of Inflation:

# Generalized Disformal Transformations

and

# Redundant Couplings

with P. Creminelli and F. Vernizzi, 1706.03578 (submitted to JCAP)

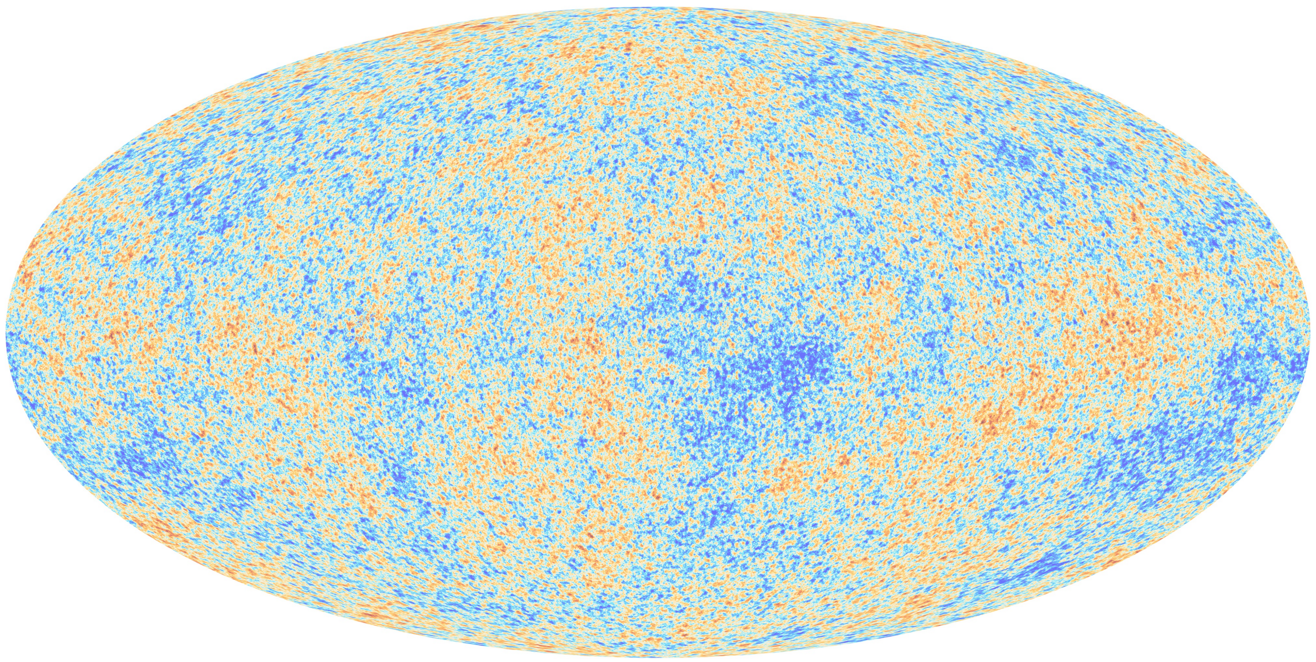
Stockholm, July 20th 2017

Inflationary observables: super-horizon correlation functions

$$\langle\zeta(\tau,\boldsymbol{k})\zeta(\tau,-\boldsymbol{k})\rangle,\quad \langle\gamma(\tau,\boldsymbol{k})\gamma(\tau,-\boldsymbol{k})\rangle$$

$$\langle\zeta(\tau,\boldsymbol{k}_1)\zeta(\tau,\boldsymbol{k}_2)\zeta(\tau,\boldsymbol{k}_3)\rangle,\ \ldots$$

$$|k_i\tau| \ll 1$$



Freedom to perform redefinitions of $\zeta$ and $\gamma$ that decay outside the horizon. (e.g.: $\zeta \to \zeta + \lambda\frac{\mathrm{d}\zeta}{\mathrm{d}t}$ )

↓

Used to simplify the action!

EFT of Inflation

- Single clock: $\phi(t)$ → ~~Time Diff.s~~

Cheung et al., 07

Unitary Gauge: perturbations are eaten by the metric.

→ $\left(t\,;\; g^{00}\,,\delta K\,,{}^{(3)}R\;\ldots\;; R,\,\delta R_{\mu\nu}\delta R^{\mu\nu}\,,\ldots\right)$

$$\mathcal{L} = \frac{M_{\rm Pl}^2}{2}\left[R + 2\dot{H}g^{00} - 2\left(3H^2 + \dot{H}\right)\right] + \ldots$$

Focus on

- Quadratic and cubic operators $\langle\zeta\zeta\rangle$ $\langle\gamma\gamma\rangle$ $\langle\zeta\zeta\zeta\rangle$ $\langle\zeta\gamma\gamma\rangle$ $\langle\zeta\zeta\gamma\rangle$ $\langle\gamma\gamma\gamma\rangle$
- Up to second order in derivatives.

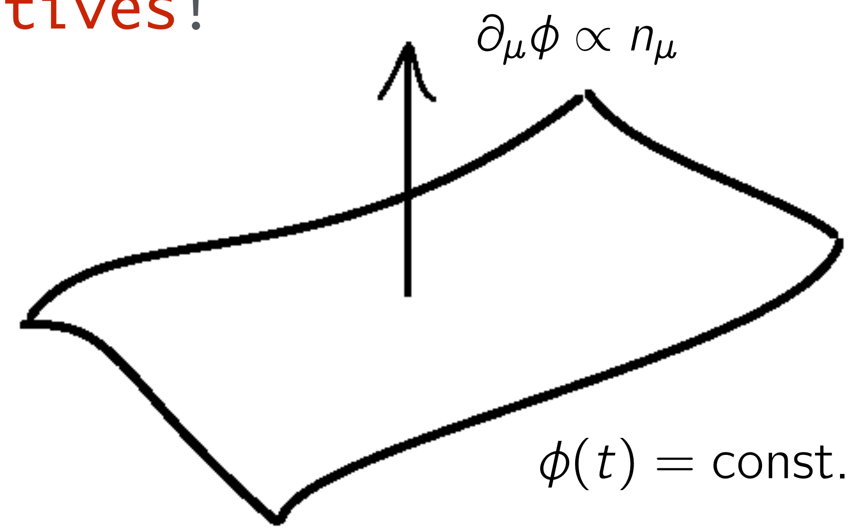
## Field redefinitions

Most generic transformation ...

$$g_{\mu\nu} \to C(t, N, K, \dots) g_{\mu\nu} + D(t, N, K, \dots) n_\mu n_\nu + E(t, N, K, \dots) K_{\mu\nu} + \dots$$

... generates operators with too many derivatives!

$$\delta S_{\rm EH} = \frac{M_{\rm Pl}^2}{2} \int \mathrm{d}^4 x \sqrt{-g}\, \underline{\underline{G_{\mu\nu}}}\, \delta g^{\mu\nu}$$




To preserve the # of derivatives in the action:

$$g_{\mu\nu} \to (f_1 + f_3\, \delta N + f_5\, \delta N^2) g_{\mu\nu} + (f_2 + f_4\, \delta N + f_6\, \delta N^2) n_\mu n_\nu$$

$(g^{00} \approx -1 + 2\delta N)$

An example

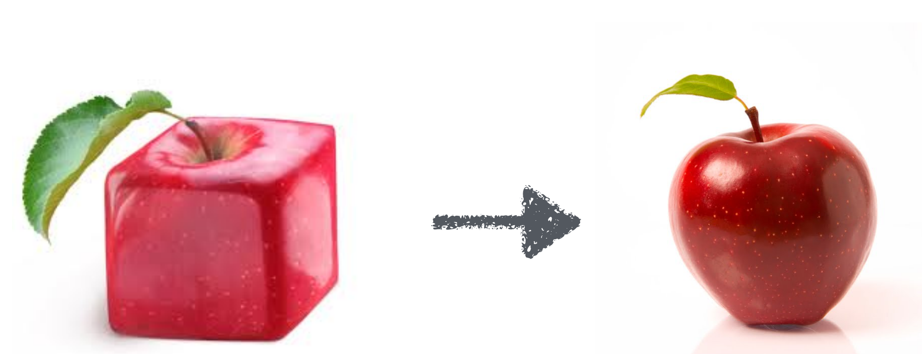
$$\mathcal{L}[g] = \mathcal{L}_{\mathrm{EH}+\phi}[g] + c_R \, {}^{(3)}R \, \delta N + c_K \, \delta N \, \delta K_{\mu\nu} \delta K^{\mu\nu}$$

Redefine $g_{\mu\nu} \to \tilde{g}_{\mu\nu} = (1 + f_3 \, \delta N) \, g_{\mu\nu} + (1 + f_4 \, \delta N) \, n_\mu n_\nu$

$$\mathcal{L}[g] = \mathcal{L}_{\mathrm{EH}+\phi}[g] + \left( c_R - \frac{f_3}{2} + \frac{f_4}{4} \right) {}^{(3)}R \, \delta N + \left( c_K - \frac{f_3}{2} - \frac{f_4}{4} \right) \delta N \, \delta K_{\mu\nu} \delta K^{\mu\nu}$$

Use $f_3$ and $f_4$ to set to zero the couplings!

Observables do not depend on $c_K$ and $c_R$!



EFTI up to cubic order in perturbations and 2 derivatives

- After integration by parts: 17 operators.

  6 field redefinitions ($f_i$) → 6 redundant couplings!

  Minimal set: 11 operators!

- Predictions for $\langle\gamma\gamma\rangle$ and $\langle\gamma\gamma\gamma\rangle$ are the same as Einstein-Hilbert.

  Creminelli, Gleyzes, Noreña, Vernizzi, 14

- All the couplings contributing to scalar-tensor-tensor action beyond EH can be removed.

  $\langle\zeta\gamma\gamma\rangle$ is not fixed!
  Still affected by changes in the scalar sector.

## Diff-like field redefinitions

Assume the action dominated by operators with no derivatives acting on the metric → $P(X)$

see e.g. Armendáriz-Picón, Damour, Mukhanov, 99
Chen, Huang, Kachru, Shiu, 06

$$\mathcal{L} = \mathcal{L}_{\rm EH} + \underbrace{M_1^4\,\delta N^2 + M_2^4\,\delta N^3}_{\to\, P(X)} + \text{“small corrections”}$$

$$X = -\frac{1}{2}\partial_\mu\phi\,\partial^\mu\phi$$

Additional transformations that mimic a time diff.:

$$\delta S_{\rm EH} = 0$$

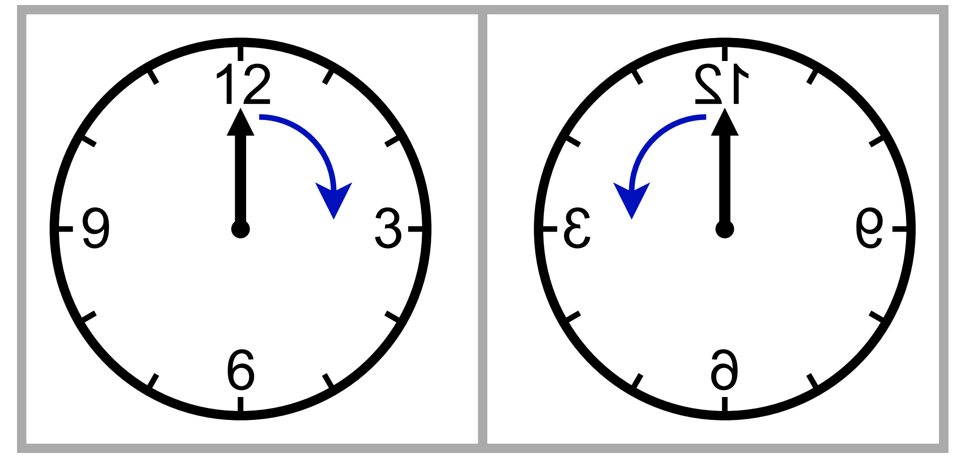
$$\delta g_{\mu\nu} = \nabla_{(\mu}\xi_{\nu)} \qquad \xi_\mu = F(t, \delta N, K)\, n_\mu$$

We remain at 2-derivative order!

- 6 transformations.
- Only three higher-derivative corrections.

## Higher order in derivatives

Focus on tensor modes (assume $\mathcal{P}$ )




- 3-derivative level

  $\langle\gamma\gamma\rangle$ does not change.

  Just 1 operator contributes to $\langle\gamma\gamma\gamma\rangle$: $\delta K^3_{\mu\nu}$

- 4-derivative level

  see also Cannone, Tasinato, Wands, 15

  Only 1 operator affects $\langle\gamma\gamma\rangle$: ${}^{(3)}R^2_{\mu\nu}$

  → Due to the coupling with $\phi$!

→ Corresponding $\langle\zeta\gamma\gamma\rangle$ can be sizable!