# Correlating features in the primordial spectra... (or, what was the inflaton?)

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Swiss Cosmology meeting, ETH Zurich, Feb $7^{th}$ 2014

# What we know:

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- Assuming $\Omega_{tot} = 1, w_\Lambda = -1, \sum_i m_\nu = 0$ ...
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| $\Omega_c h^2 = 0.1196 \pm 0.0031$ | $ln\,(10^{10} A_s) = 3.103 \pm 0.072$ |
| $\theta_{MC} = 0.00104 \pm 0.00068$ | $\tau = 0.097 \pm 0.038$ |

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- Taken literaly, on face value– a staggering statement!
- ∃ a *single* effectively light degree of freedom at $\sim \epsilon^{1/4} 10^{16} GeV$ .
  - whose field modes began in the relevant vacuum state (BD)
  - whose self interactions and interactions with other fields are sufficiently weak or irrelevant *throughout* inflation
  - which at the same time couples strongly enough to some sector that contains the standard model so that efficient (pre)heating occurs...

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- It goes without saying that any signatures of primordial gravity waves would be a great boone...
- But what if all we ever get to see are the correlators of the adiabatic mode? What could we still meaningfully hope to know? (At the level of the 2-pt function, $\exists$ dualities between very different backgrounds. Wands, arXiv:gr-qc/9809062 )

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- w/ 3d info from LSS (up to $k_{NL} \sim 0.1 Mpc^{-1}$ ) and 21 cm promising us access to never before seen comoving scales ($k \sim \mathcal{O}(10^2) Mpc^{-1}$ ), if present, features can be detected much more cleanly.

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- Might correlations of a particular class allow us to extract information about the background evolution?

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- The EFT expansion of the adiabatic mode knows about the background– terms in the derivative expansion more and more constrained as the background becomes more symmetric (i.e. dS–like).
- What can we extract about the background in principle?

# Features, an analytic understanding

One can understand how any type of feature in the 2-pt correlation function can be generated analytically:

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- Defining $w(\tau) := c_0^2 - c_s^2(\tau)$, $W(\tau) := \frac{z''}{z} - \frac{z_0''}{z_0}$ , and consider these to be uniformly bounded by unity.

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- We can thus write $S_2 = S_{2,free} + S_{2,int}$ , with:
  $S_{2,free} = \frac{1}{2}\int d^4x \left(v'^2 - c_0^2(\nabla v)^2 + \frac{z_0''}{z_0}v^2\right)$
  $S_{2,\mathrm{int}} := \frac{1}{2}\int d^4x \left(w(\tau)(\nabla v)^2 + W(\tau)v^2\right)$
  and treat the $S_{2,int}$ as a perturbative interaction.

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Treating $w(\tau)$ and $W(\tau)$ as independent perturbations, one can compute the corrections to the 2-pt correlator of the fiducial background via as

- $$\delta_W \langle \hat{v}_{k_1}(\tau)\, \hat{v}_{k_2}(\tau)\rangle \;= (2\pi)^3\, \delta^3(\vec{k}_1 + \vec{k}_2) \int_{\tau_0}^{\tau} d\tau' \;2W(\tau') \Im \left\{ G^0_{k_1}(\tau,\tau')\, G^0_{k_2}(\tau,\tau')\right\}$$

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- Presuming that the fiducial background is a slow roll inflating attractor, one can compute the leading order correction to the power spectrum: $$\frac{\Delta\mathcal{P}_{\mathcal{R}}}{\mathcal{P}_{\mathcal{R}}}(k) = -\frac{8\pi^3}{c_0 k} \int_{\tau_0}^{0} d\tau \{W(\tau), k^2 w(\tau)\} \Im \left\{ e^{2ic_0 k\tau} \left(1 + \frac{i}{c_0 k\tau}\right)^2 \right\}$$

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- Induced features only have finite support in $k$ if the interaction potentials $W(\tau)$ and $w(\tau)$ do not contain arbitrarily fast variations*.
- * Too sudden changes are limited by the requirements that the inflaton embed itself consistently in some UV completion, requiring a consistent derivative expansion for the action for inflaton field and its fluctuations.

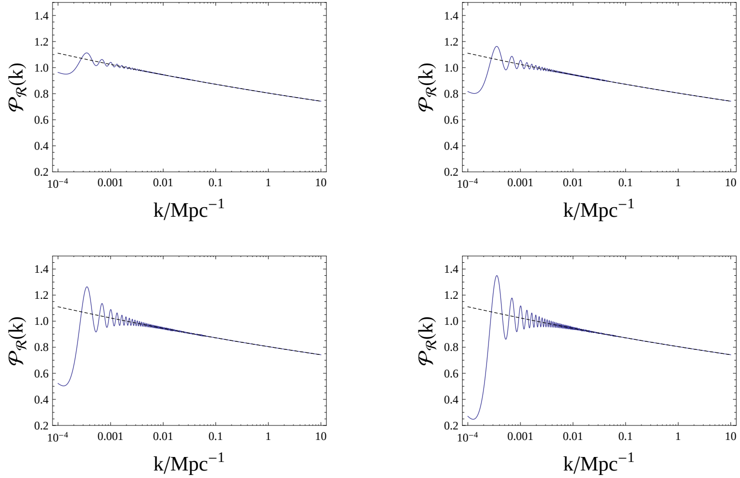


Figure : Relaxation to the attractor with $W(\tau) = \lambda e^{-(\tau-\tau_0)\mu}$, with $\lambda = 5 \times 10^{-5}/(4\pi^4), \tau_0 = -10^4$ and with $\mu$ running from $2, 1, 0.5$ and $0.35$ in the upper left, upper right, lower left and lower right panels, respectively. For fundamental physics motivation for beginning inflation off the attractor, see Dudas, Kitazawa, Patil, Sagnotti, arXiv:1202.6630

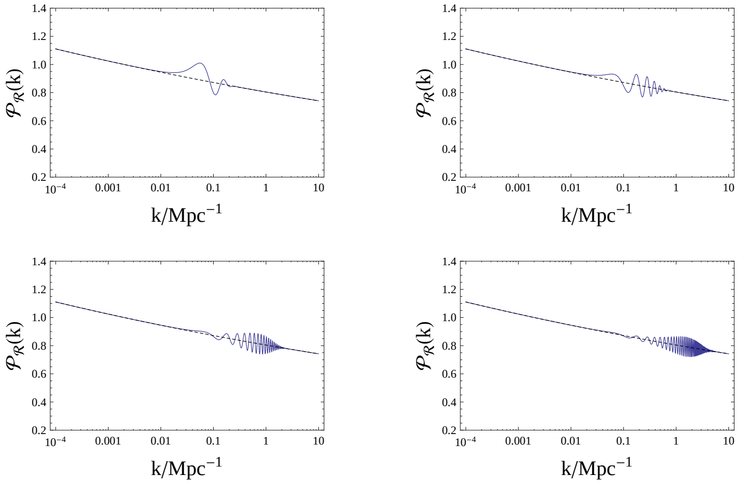


Figure : Transient drop in $c_s$ with $w(\tau) = \lambda\tau^2 e^{-(\tau-\tau_0)^2\mu}$, with $\lambda = 2 \times 10^{-4}/(4\pi^4), \tau_0 = -30$ and with $\mu$ running from $0.01, 0.1, 1$ and $5$ in the upper left, upper right, lower left and lower right panels, respectively.

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- Given that features in the power spectrum tend to get washed out at large angular scales, even if they were present, we may never know any better.

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- Classifying the various possibilities is a work in progress (under certain assumptions for the inverse problem to be tractable)...

# The effective action

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arXiv:1201.4848; Achúcarro et al arXiv:1205.0710

# Correlated non-Gaussianities

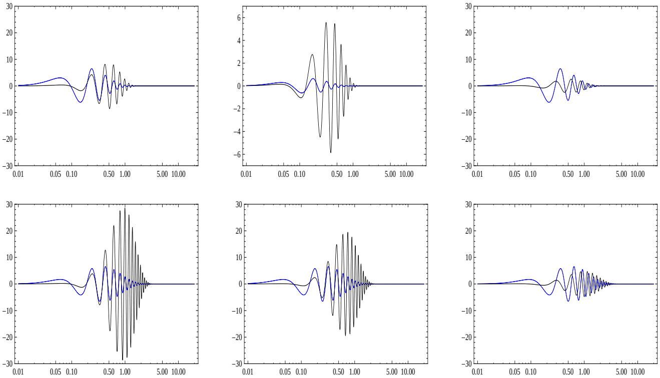


Figure : $f_{NL}^{eq}$ vs $\frac{\Delta P}{P}$ (left), $f_{NL}^{f}$ vs $\frac{\Delta P}{P}$ (middle) and $f_{NL}^{sq}$ vs $\frac{\Delta P}{P}$ (right) for $\tau_0 k_* = -11$, $c = 0.8$ (top) and $\tau_0 k_* = -11$, $c = 1.5$ (bottom) respectively for the 'cosh' drop in the speed of sound given by $1 - c_s^2 = -\frac{\Delta_{max}}{Cosh[c(\tau - \tau_0)]}$.

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Prominent features could be imprinted onto primordial observables, whose correlations at commensurate scales encode the embedding of inflation into some parent theory.

- The positive detection of such (correlated) features in future data sets would help us better understand the true nature of the inflaton.
- Features induced by varying $c_s$ can in principle, be imprinted on very short scales (where the statistics for their detection improve markedly).
- Encode the influence on heavy fields on the dynamics of the adiabatic mode.
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- The real fun is yet to begin (LSS, 21cm, spectral distortion)!