Correlating features in primordial correlators, or, what was the inflaton?

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CERN

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- Taken literally, on face value– a staggering statement!
- $\exists$ 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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- But what if all we are stuck with 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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- But maybe there is more lurking in the data than meets the (minds) eye?

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- w/ 3d info from LSS (up to $k_{NL} \sim 0.1 Mpc^{-1}$), 21 cm and spectral distortions promising us access to never before seen comoving scales ($k \sim \mathcal{O}(10^4) Mpc^{-1}$), if present, features can be detected much more cleanly. Huang, Verde, Vernizzi, arXiv:1201.5955

Based on/ inspired by

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- arXiv:1409.xxxx, *in preparation*

  J. Chluba, J. Hamann, S.P. Patil

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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- 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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- * Too sudden changes are limited by requiring a consistent derivative expansion for the action for inflaton field and its fluctuations.

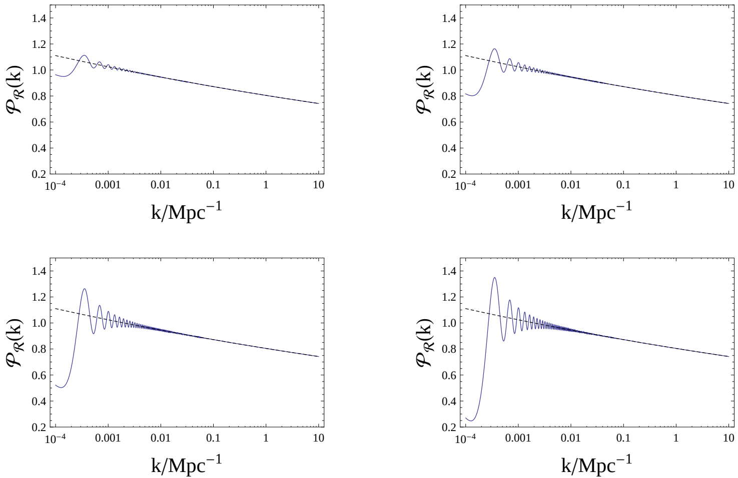

Figure : Relaxation to the attractor with $W(\tau) = \lambda e^{-(\tau-\tau_0)\mu}$, with $\lambda = 5 \times 10^{-5}/(4\pi^4), \tau_0 = -10^4$ and with μ running from $2, 1, 0.5$ and 0.35 in the upper left, upper right, lower left and lower right panels, respectively. For fundamental physics motivation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

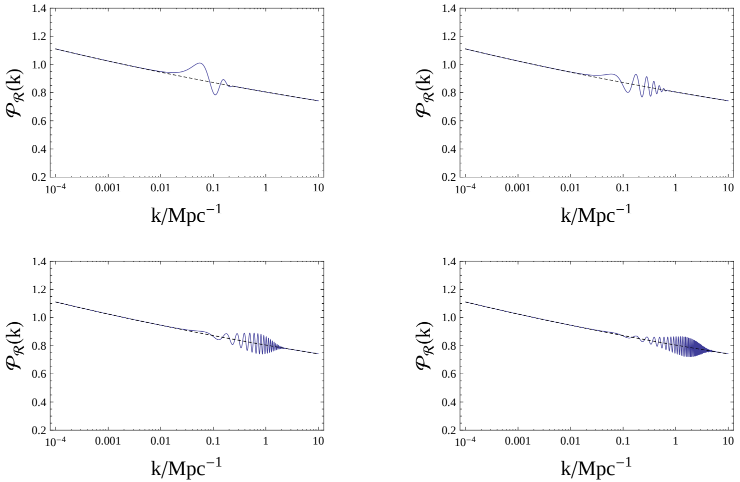

Figure : Transient drop in c_s with $w(\tau) = \lambda \tau^2 e^{-(\tau-\tau_0)^2 \mu}$, with $\lambda = 2 \times 10^{-4}/(4\pi^4), \tau_0 = -30$ and with μ running from $0.01, 0.1, 1$ and 5 in the upper left, upper right, lower left and lower right panels, respectively.

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- From the perspective of the EFT of inflation, transient changes in c_s occur very naturally– encode the influence of heavy fields on the dynamics of the adiabatic mode *completely consistent with decoupling, adiabaticity, the persistence of slow roll, and the validity of the single field regime.* Achucarro et al. 2010- 2012

Three notions of ‘heavy’

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- The effective theory must account for all the curvature scales present in the parent theory.

EFT of Inflation

The Effective field theory of inflation is an active and current area of interest.

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- * In concrete realizations, it turns out that the couplings can temporarily become larger than order unity at various points along the inflaton trajectory (consistent with slow roll), and can compete with the H^2/M^2 suppression enough to come within the threshold of experimental sensitivity.

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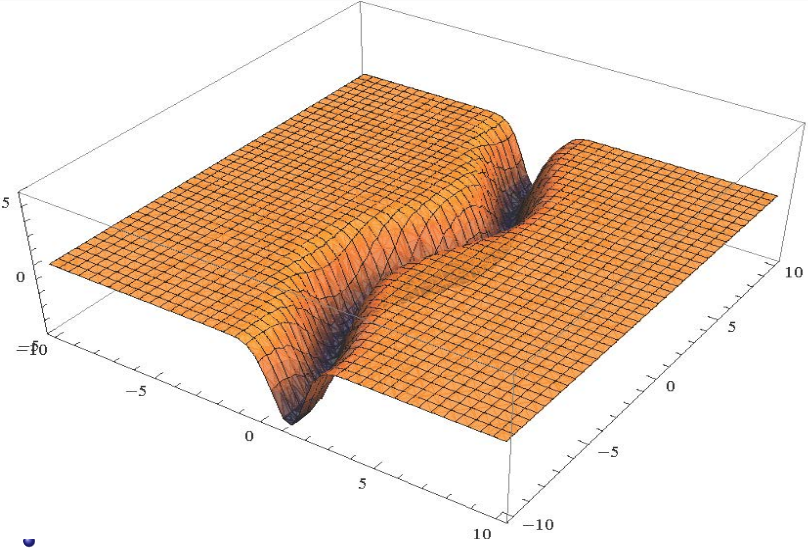

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- Non-trivial information about the higher dimensional operators in the EFT– appropriately limited information of the parent theory.

The view from the trajectory

Practically, we are specifically interesting in computing the perturbations around a background trajectory. Consider the (two field) action

Achúcarro et al arXiv:1201.6342

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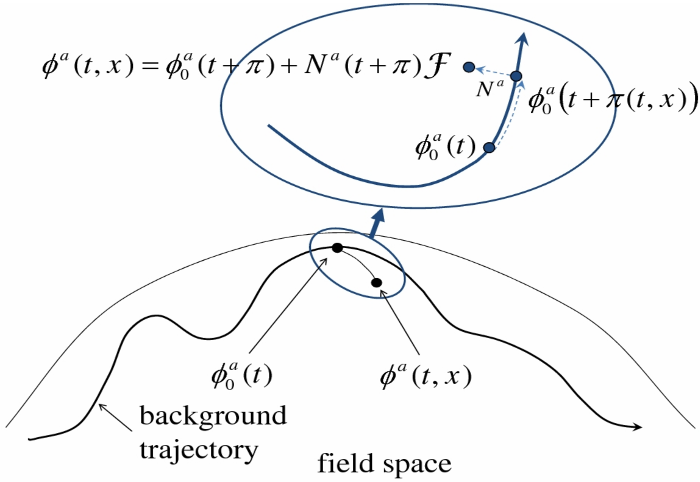
- We now define field fluctuations $\pi(t,x)$ and $\mathcal{F}(t,x)$ as $\phi^a(t,x) = \phi^a_0(t+\pi) + N^a(t+\pi)\mathcal{F}$

The view from the trajectory



The effective action

Expanding the action, using Frenet-Serret relations and integrating out $\mathcal{F}$ to order M_{eff}^{-4} results in

-

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Achúcarro et al arXiv:1005.3848; Baumann and Green arXiv:1102.5343

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- Flat gauge ($\mathcal{R} \equiv 0$)

$$S_{\rm eff} = -\int d^4x a^3 M_{pl}^2 \dot{H} \left\{ c_s^{-2}\dot{\pi}^2 - \frac{(\nabla\pi)^2}{a^2} + \left(c_s^{-2} - 1\right)\dot{\pi}\left[\dot{\pi}^2 - \frac{(\nabla\pi)^2}{a^2}\right] + \left(c_s^{-2}-1\right)^2 \frac{\dot{\pi}^3}{2} - 2\frac{\dot{c}_s}{c_s^3}\pi\dot{\pi}^2 - 2H\eta_{\parallel}\pi\left[c_s^{-2}\dot{\pi}^2 - \frac{(\nabla\pi)^2}{a^2}\right]\right\}$$

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- EFT valid so long as $|\dot{c}_s| \ll M|1 - c_s^2| \to \dot{\omega}_+/\omega_+^2 \ll 1$ Cespedes et al

arXiv:1201.4848; Achúcarro et al arXiv:1205.0710

Correlated non-Gaussianities

Assuming that the speed of sound departs from unity ‘perturbatively’ and only transiently:

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Presuming that $\Delta_s \leq \mathcal{O}(10^{-1})$, one can stop at leading order in Δ_s and slow roll– allows us to invert in terms of changes in the power spectrum:

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- Consider the features induced by various functional forms for the drops in the speed of sound, and compute $f_{NL}^{\triangle} := \frac{40}{3} \frac{k_1^3 k_2^3 k_3^3}{\sum_i k_i^3} \left(\frac{H^4}{M_{pl}^4 \epsilon^2}\right)^{-1} B_{\mathcal{R}}(\vec{k}_1, \vec{k}_2, \vec{k}_3)$

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- In general: $f_{\rm NL}^{\triangle} \sim c_0^{\triangle}(\vec{k}) \frac{\Delta \mathcal{P}_{\mathcal{R}}}{\mathcal{P}_{\mathcal{R}}} + c_1^{\triangle}(\vec{k}) \left(\frac{\Delta \mathcal{P}_{\mathcal{R}}}{\mathcal{P}_{\mathcal{R}}}\right)' + c_2^{\triangle}(\vec{k}) \left(\frac{\Delta \mathcal{P}_{\mathcal{R}}}{\mathcal{P}_{\mathcal{R}}}\right)''$ with all shape dependence and information of the parent theory contained in the $c_i^{\triangle}$.

Correlated non-Gaussianities

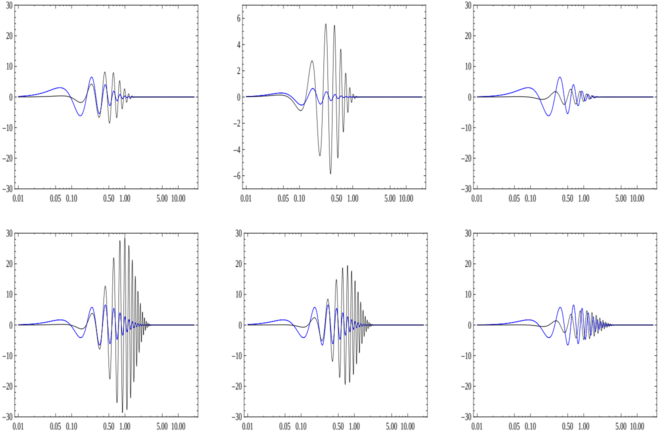

Figure : f_{NL}^{eq} vs $\frac{\Delta P}{P}$ (left), f_{NL}^{f} vs $\frac{\Delta P}{P}$ (middle) and f_{NL}^{sq} vs $\frac{\Delta P}{P}$ (right) for $\tau_i k_* = -11$, $\tau_f k_* = -9$, $c = 0.8$ (top), $\tau_i k_* = -11$, $\tau_f k_* = -6$, $c = 0.8$ (middle) and $\tau_i k_* = -11$, $\tau_f k_* = -6$, $c = 1.5$ (bottom) respectively, for the 'top hat' drop in the speed of sound given by $\Delta_s = -\frac{\Delta_{max}}{2}\left(Tanh[c(\tau - \tau_i)] - Tanh[c(\tau - \tau_f)]\right)$.

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- The real action is yet to begin (LSS, 21cm, spectral distortion).