Can we spoil the robust predictions?

THEORY OF COSMOLOGICAL PERTURBATIONS

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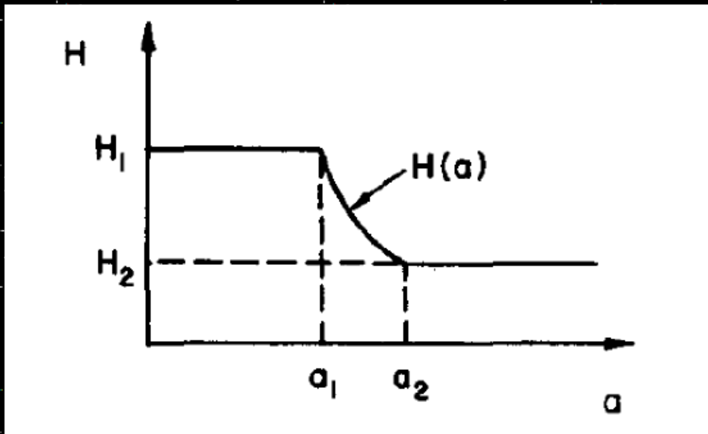


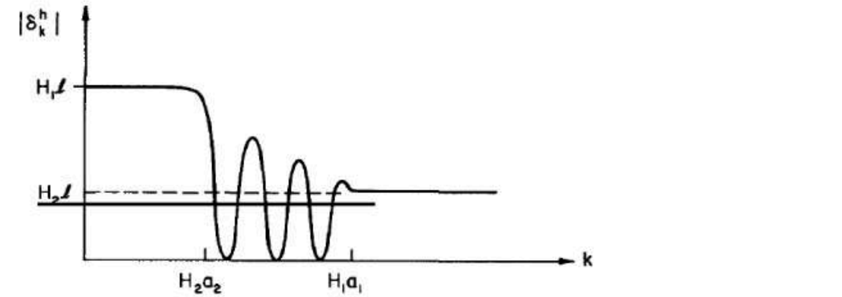


Fig. 18.7. Power spectrum $\delta_h \equiv h$ of gravitational radiation in the double inflation model of (18.40) with the ratio of Hubble constants $H_1/H_2 = 10$.

[redacted]

Note that the effect discussed in this section can arise for both adiabatic and entropy perturbations.

[redacted]

it is possible to obtain a suppression of the long-wavelength part of cosmological perturbation

[redacted]

$$S = \int [\tfrac{1}{2}\chi_{;\mu}\chi^{;\mu} - V(\chi) + \tfrac{1}{2}\varphi_{;\mu}\varphi^{;\mu} - \tfrac{1}{2}m_0^2\varphi^2 - V_1(\chi, \varphi, \ldots)]\sqrt{-g}\,\mathrm{d}^4x\,,$$

[redacted]

nontrivial spectra with mountains and valleys can also be obtained [redacted]

It is also possible to generate non-Gaussian fluctuations [redacted]

However, this procedure is extremely unappealing since it implies a complete loss of predictability.

MFB, Physics Report, 1992

Inflation is THE theory only when it is understood as the stage of unbroken accelerated expansion due to the same ingridient which is responsible for quantum fluctuations.

Otherwise it is rubbish without any predictions!!!

In this case it is unbeatable as predictive theory because it allows us to calculated the effect of amplification of quantum fluctuations in completely controlable weak coupling regimes

while most alternatives cannot even compete with "rubbish inflation" in a sense of controlable reproduction of outcome for quantum fluctuations

COSMOLOGY - Theology = $\exp(Ht)$

during at least 70 H^{-1}, but less than 10^6 H^{-1} $\rightarrow$

no any problems with predictions, which could falsify the theory in Popper's sense

What is relevant for predictions?

$-\varepsilon$ energy density

$-p$ pressure

$$1 + w \equiv \frac{\varepsilon + p}{\varepsilon} \ll 1$$

during last 70 e-folds $(a = a_f \cdot e^{-N})$

$a)$ $1 + w \ll 1$ for $N \gg 1$

$b)$ $1 + w \approx O(1)$ for $N \simeq O(1)$

$c)$ $1 + w$ is a smooth function of N

Inflation is not a unique theory, but rather a class of models based on similar principles.

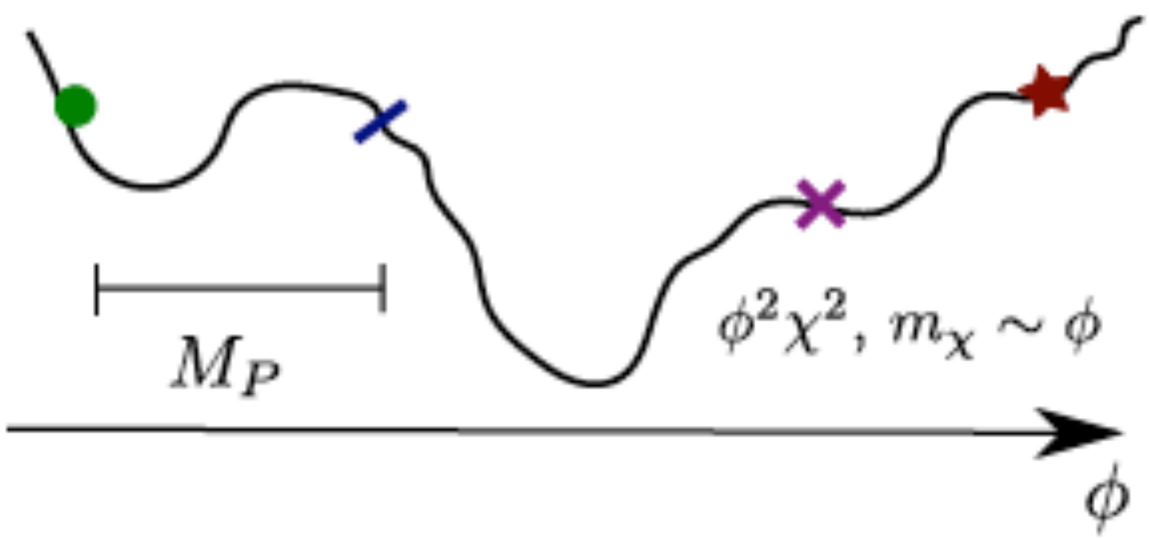
WRONG!

The only purpose of inflationary models relevant for observation is a maping

$$V(\varphi) \quad \text{to} \quad p \approx -\varepsilon$$

and this maping happened to be not crucial for robust predictions but important only for excluding definite potentials $V(\varphi)$, which anyway we will never be able to verify in any other independent experiments

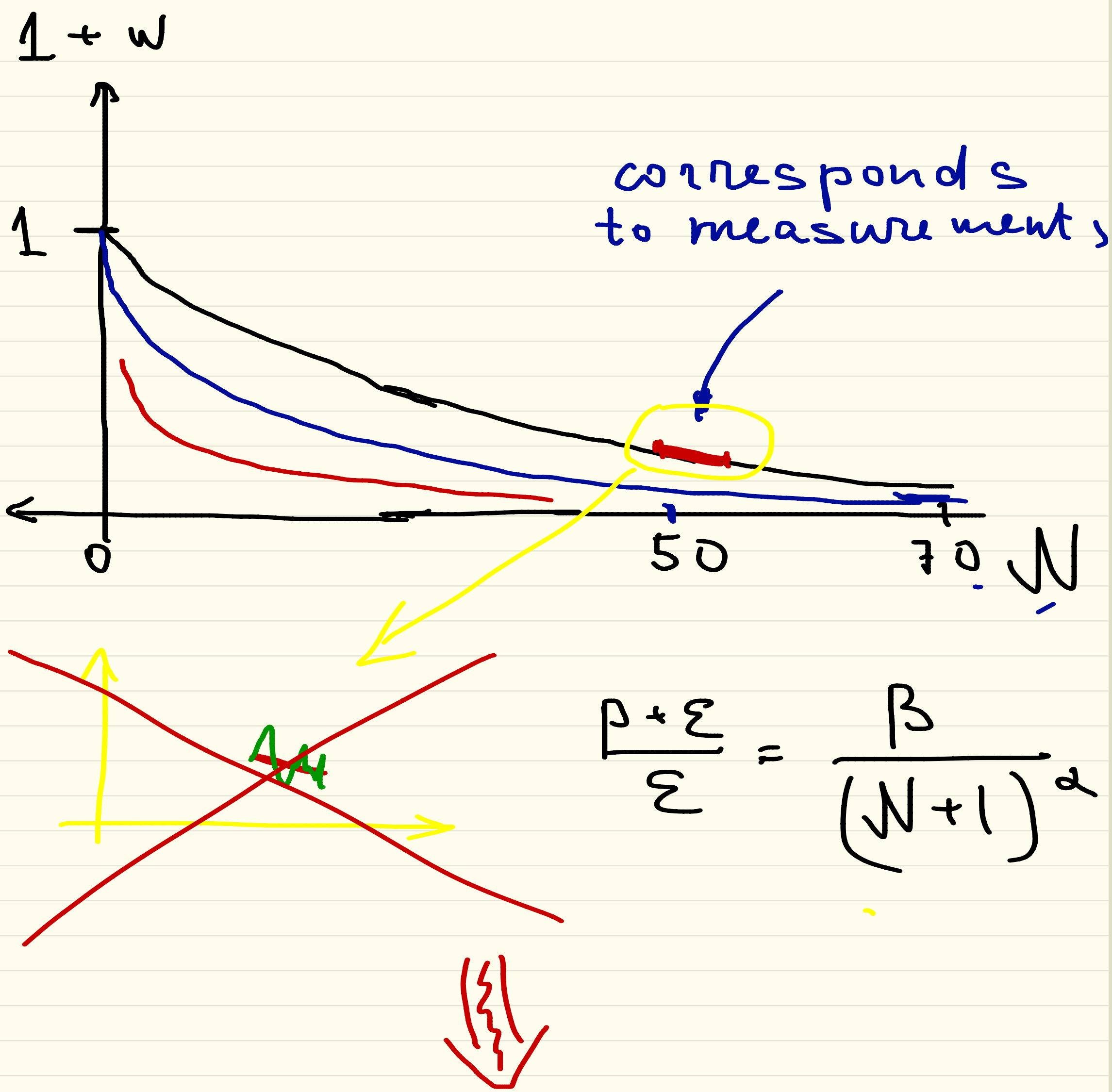
$$V(\tau,\theta) = \frac{12W_0^2\xi}{(4V_{\mathrm{m}}-\xi)(2V_{\mathrm{m}}+\xi)^2} + \frac{D_1 + 12e^{-2a_2\tau}\xi A_2^2}{(4V_{\mathrm{m}}-\xi)(2V_{\mathrm{m}}+\xi)^2} + \frac{D_2 + \frac{16(a_2A_2)^2}{3a\lambda_2}\sqrt{\tau}e^{-2a_2\tau}}{(2V_{\mathrm{m}}+\xi)} \tag{25}$$
$$+\frac{D_3 + 32e^{-2a_2\tau}a_2A_2^2\tau(1+a_2\tau)}{(4V_{\mathrm{m}}-\xi)(2V_{\mathrm{m}}+\xi)} + \frac{D_4 + 8W_0A_2e^{-a_2\tau}\cos(a_2\theta)}{(4V_{\mathrm{m}}-\xi)(2V_{\mathrm{m}}+\xi)}\left(\frac{3\xi}{(2V_{\mathrm{m}}+\xi)} + 4a_2\tau\right) + \frac{\beta}{V_{\mathrm{m}}^2}.$$



$a)\ 1+w \ll 1$ for $N \gg 1$

$b)\ 1+w \approx O(1)$ for $N \simeq O(1)$

$c)\ 1+w$ is a smooth function of N



$$\frac{P+\varepsilon}{\varepsilon} = \frac{B}{(N+1)^{\alpha}}$$

PREDICTIONS

("smoking guns"-nonconfirming any of them would falsify THE theory)

- flat universe
- adiabatic perturbations
- small non-gaussianity ($f_{NL} \sim O(1)$)
- red-tilted spectrum

$$\Phi^2 \propto \lambda^{1-n_S}$$

$$1 - n_S = 3(1+w) - \frac{d\ln(1+w)}{dN}$$

of the faint ripples that we detect in the cosmic microwave background (CMB). First, the ripples should be nearly scale-invariant, meaning that they have nearly the same intensity at

The theory always predicts red-tilted spectrum

From GR content ⇒ one postulate ≡
stage of accelerated expansion ⟹
explanation of hom, isotr.
\+ 2 nontrivial predictions

– $\Omega_{total} = 1 \pm 10^{-5}$

– spectrum of pertur.

spectrum is never HZ for generic inflation. It is tilded

$$\Phi_\lambda^2 = \frac{\overset{10^{-12}}{\varepsilon}}{\varepsilon_{Pl}} \frac{1}{\underbrace{1+p/\varepsilon}_{1/50}}\Bigg|_{\lambda^{-1}=Ha}$$

$$n_s - 1 = -3\Big(1+\underbrace{\frac{p}{\varepsilon}}_{\to 0}\Big)_{\lambda^{-1}=Ha} - \frac{1}{H}\Big(\ln\Big(1+\underbrace{\frac{p}{\varepsilon}}_{\to 0}\Big)\Big)$$

$$0.9 \overset{?}{\lesssim} n_s < 0.96 \quad !$$

not too much grav. waves!
Gaussian perturbations

Cambridge, 2000

[1]. Contrary to an erroneous belief inflation does not predict the scale-invariant, Harrison-Zel'dovich spectrum. The spectral index should be in the range of $0.92 < n_s < 0.97$. The physical

V. Mukhanov, CMB, Quantum Fluctuations
and the Predictive Power of Inflation,
arXiv:astro-ph/0303077 (2003)

Red-tilted log spectrum (MC, H, 1981-1982) $\rightarrow$

$$n_S = 1 - \frac{A}{\ln(B\lambda_{gal} / \lambda_{CMB})},$$

where $A > 1,5$ and $B \simeq 1 - 100$ depending on $50 < N < 55$ $\rightarrow$

$$n_S < 0.97$$

irrespective of any particular model!

L.P. 9/6/2003:

We are writing a proposal to get money to do our small angular scale CMB experiment. If I say that simple models of inflation require n_s=0.95+/-0.03 (95\% cl) is it correct?

I'm especially interested in the error. Specifically, if n_s=0.99 would you throw in the towel on inflation?

V.M. 9/8/2003

The "robust" estimate for spectral index for inflation is 0.92<n_s<0.97. The upper bound is more robust than lower. The physical reason for the deviation of spectrum from the flat one is the nessesity to finish inflation....

If you find n_s=0.99 +/- 0.01 (3 sigma) I would throw in the towel on inflation.

The unavodable uncertainty in B is bad news for "model bilders"!
It leads to theoretical uncertainty in prediction of n_s of order 0.005
for any model of inflaton and hence further increasing of expermental
accuracy in n_s will not no help us much in model selecton

Further predictions ("non-smoking guns"):

- Primordal gravitational waves
- Nongaussianities due to nonlinearity of

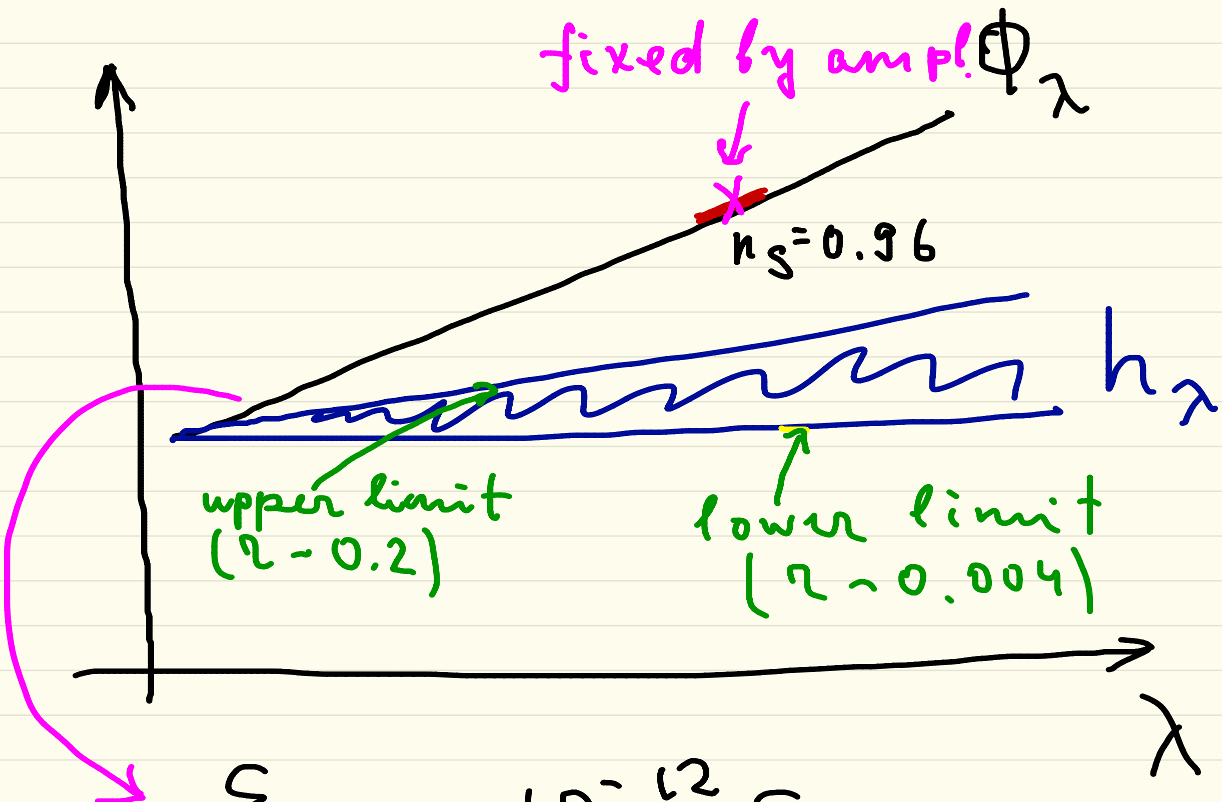
Einstein equation (3,4,...points correlaton functions)

There must be primordial gravi tatonal waves

$$r \equiv \frac{T}{S} = 24 \cdot (1 + p / \varepsilon) = \frac{\beta}{N^{\alpha}}$$

No a priori low bound on their ampltude!

but if n_s is measured



$$\varepsilon_{end} \sim 10^{-12} \, \varepsilon_{pe}$$

However, keeping mind theoretical and experimental uncertainty, n_s within 2-sigma can be equal to 0.95.
In this case the lower bound on r becomes 0.0006
(unrealistic from the point of view of future measurements)

- Thus, detection of the primordial gravitational field will provide us an extra confirmation that quantum fluctuations were amplified on the stage of accelerated expansion.
- Failing to detect them at the level 0.04 would not have any implications and in no way can be considered as a prove of alternative for amplification of quantum fluctuation

Non-gaussianities

$$\Phi = \Phi_g + f_{NL}\Phi_g^2$$

$f_{NL} \simeq 0.04$ from inflation and $f_{NL} \simeq 2-4$ from subsequent evoluton of perturbations

- What are the perspectives of measuring f?

Not extremely promising