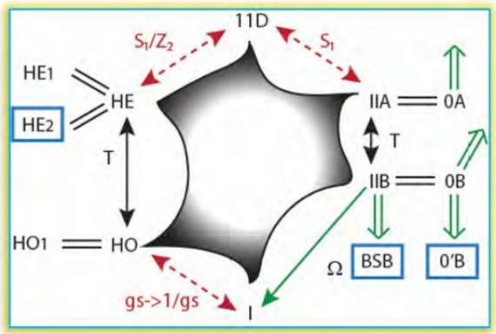
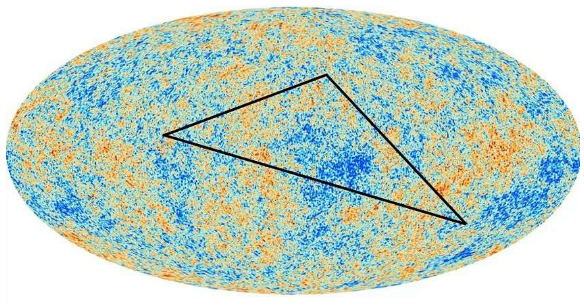
Non-Gaussian Features of a String-Inspired Pre-Inflation

Plan:

1. Non-supersymmetric 10D strings
2. *Climbing Scalar* dynamics
3. Non-Gaussian features
4. Future prospects



Non - Gaussianity



IMPRS Recruitment Workshop

MAX-PLANCK-INSTITUT FÜR PHYSIK

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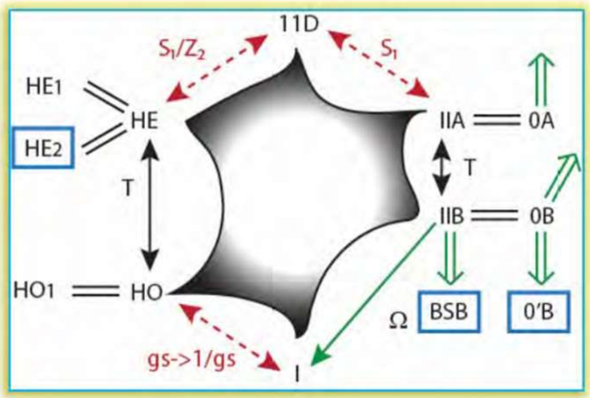
Mario Meo

Non-supersymmetric 10D strings



(Dixon, Harvey, 1986; Alvarez-Gaumé, Ginsparg, Moore, Vafa, 1986)

$SO(16)\times SO(16) \quad (\gamma = 5/2)$

(Sagnotti, 1995)

$O'_B: \ (S)U(32): \quad (\gamma = 3/2)$

(Sugimoto, 1999; Antoniadis, Dudas, Sagnotti, 1999)

$\mathrm{Usp}(32): (\gamma = 3/2)$

All these three models ARE NOT defined around 10D Minkowski space, since the breaking of supersymmetry induces an important **back-reaction**. This is signaled by the emergence of a runaway **(“tadpole”) potential** for the dilaton, which takes the form

$$\Delta S = -T \int d^{10}x \, \sqrt{-g}\, e^{\gamma \phi}$$

The cosmological behavior **changes drastically** for $\gamma \geq 3/2$! → **CLIMBING SCALAR**

(Dudas, Mourad, 2000; Russo, 2004; Dudas, Kitazawa, Sagnotti, 2010)

Climbing scalar dynamics

(Dudas, Kitazawa, Sagnotti, 2010)

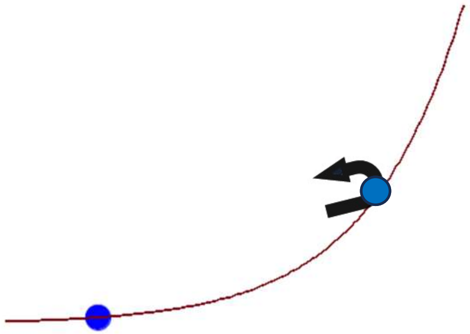
Action for the **dilaton** field ϕ

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{2k^2}R - \frac{1}{2}(\partial\phi)^2 - V(\phi)\right]$$

$$V(\phi) = \frac{M^2}{2}\left(e^{\sqrt{6}\phi} + \left[e^{\sqrt{6}\,\gamma\phi}\right]\right)$$

"Hard" exponential

"Mild" exponential



Climbing scalar dynamics

(Dudas, Kitazawa, Patil, Sagnotti, 2012)

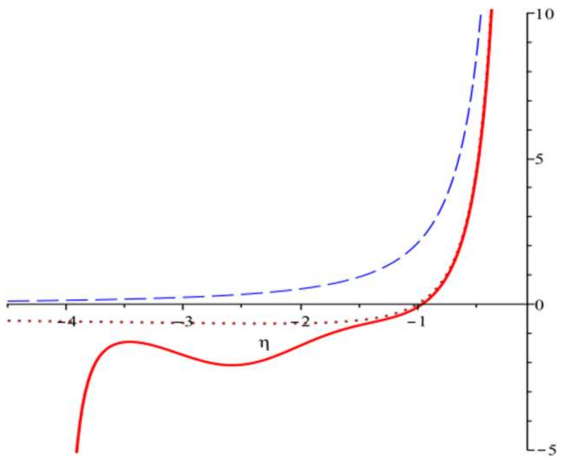
Scalar perturbation equation:

$$u_k''(\eta) + \left(k^2 - W_S(\eta)\right)u_k(\eta) = 0$$

In order to model the intersection with the η-axis

$$\nu = \frac{3}{2}\frac{1-\gamma^2}{1-3\gamma^2} \qquad W_S(\eta) = \frac{\nu^2 - \frac{1}{4}}{\eta^2} - \Delta^2$$

Δ is a **new scale**



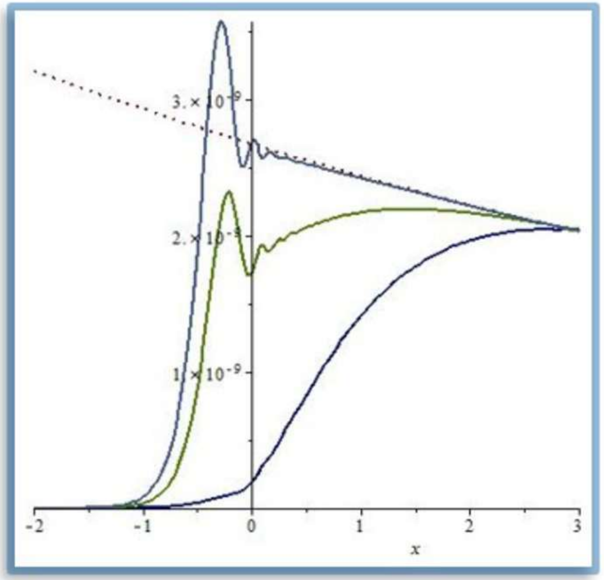
Power Spectrum

$$P_\zeta(k) \propto \frac{k^3}{(k^2+\Delta^2)^{2-\frac{n_s}{2}}} \qquad n_s - 1 = 3 - 2\nu$$

Climbing scalar dynamics

$$P_\zeta(k) \propto \frac{k^3}{(k^2+\Delta^2)^{2-\frac{n_s}{2}}} \quad \rightarrow \quad k^{n_s-1}$$

(Dudas, Kitazawa, Patil, Sagnotti, 2012)



(Gruppuso, Kitazawa, Mandolesi, Natoli, Sagnotti, 2015)

Comparison with CMB:

$$\Delta = (0.351 \pm 0.114) \times 10^{-3}\ \mathrm{Mpc}^{-1}$$

$$\Delta_{\rm inf} = 4 \times 10^{12}\, e^{N-60}\ \mathrm{GeV}$$

Climbing scalar dynamics

Motivations:

1. It provides a mechanism to inject slow-roll inflation
2. It provides an explanation for the low-l depression of the CMB angular Power Spectrum

Non-Gaussian features

$$\langle \zeta_{\boldsymbol{k_1}} \zeta_{\boldsymbol{k_2}} \zeta_{\boldsymbol{k_3}} \rangle$$

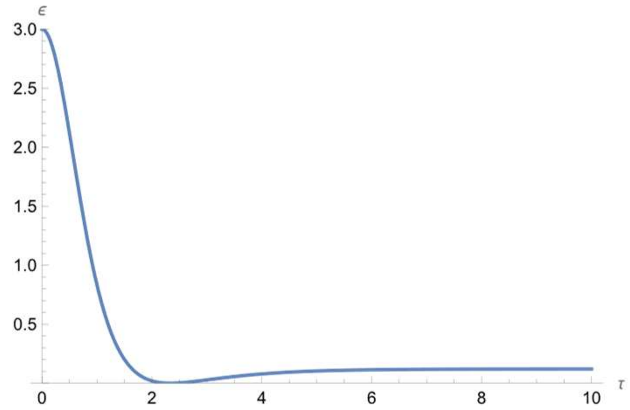
- Applying the **consistency relation**:

$$\lim_{k_3 \to 0} \langle \zeta_{\boldsymbol{k_1}} \zeta_{\boldsymbol{k_2}} \zeta_{\boldsymbol{k_3}} \rangle = (2\pi)^3 \delta^{(3)}(\boldsymbol{k_1} + \boldsymbol{k_2} + \boldsymbol{k_3})(1 - n_s) P_\zeta(k_1) P_\zeta(k_3) \quad \rightarrow \quad f_{NL}(k) \sim 3 - 2\nu - 2\nu \left(\frac{\Delta}{k}\right)^2$$

- Time dependence of the **slow-roll parameter**

$$\epsilon(\tau) \begin{cases} \text{pre} - \text{inflation} \quad \epsilon \sim 3 \\ \text{scalar inversion } \dot{\varphi} \sim 0 \rightarrow \quad \epsilon \sim 0 \\ \text{inflation} \quad \epsilon \ll 1 \end{cases}$$

The Non-Gaussian integral can be divided into **three regions** dictated by the behaviour of ϵ.



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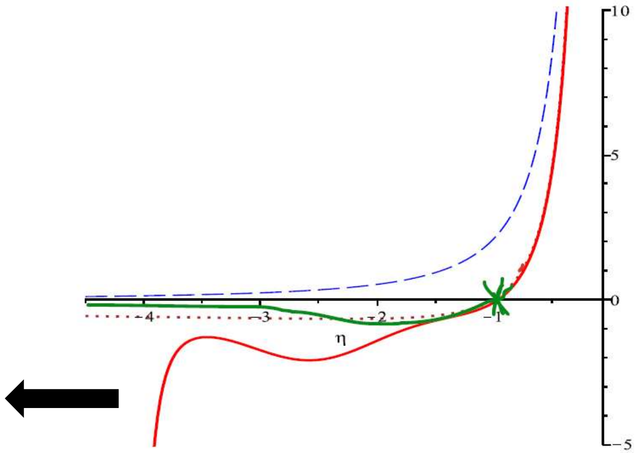
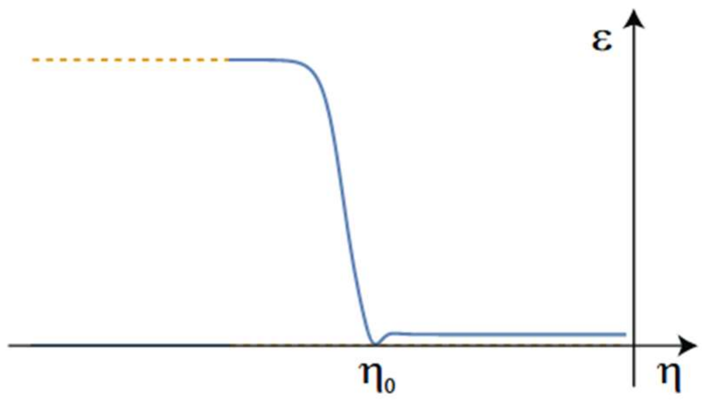
Non-Gaussian features

Background setup: extending the attractor we can avoid the singularity and work in **quasi-dS** background



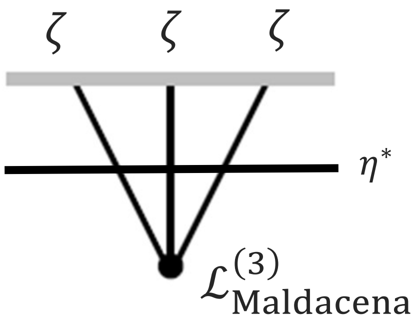


Non-Gaussian features

$\langle \zeta_{k_1}\zeta_{k_2}\zeta_{k_3}\rangle$ integrals

- Pre-inflation: big $\epsilon \sim 3$
- Climbing contribution
- Inflation: $\epsilon \ll 1$ Maldacena calculation (Maldacena, 2002)

There is a **cut η^*** due to the presence of Δ



$$\left(\int_{-\infty^-}^{\eta^*-\alpha}\frac{d\eta}{\epsilon_1}+\int_{\eta^*-\alpha}^{\eta^*+\alpha}\frac{d\eta}{\epsilon_0}+\int_{\eta^*+\alpha}^{0}\frac{d\eta}{\epsilon_2}\right)a^4(\eta)G'_{k_1}(0,\eta)G'_{k_2}(0,\eta)G_{k_3}(0,\eta)+\text{perms}$$

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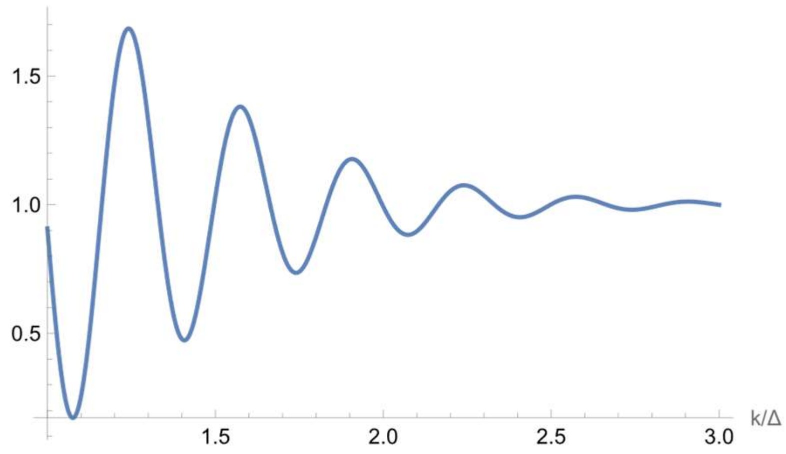
Non-Gaussian features

$\langle \zeta_{\boldsymbol{k}_1} \zeta_{\boldsymbol{k}_2} \zeta_{\boldsymbol{k}_3} \rangle$ features:

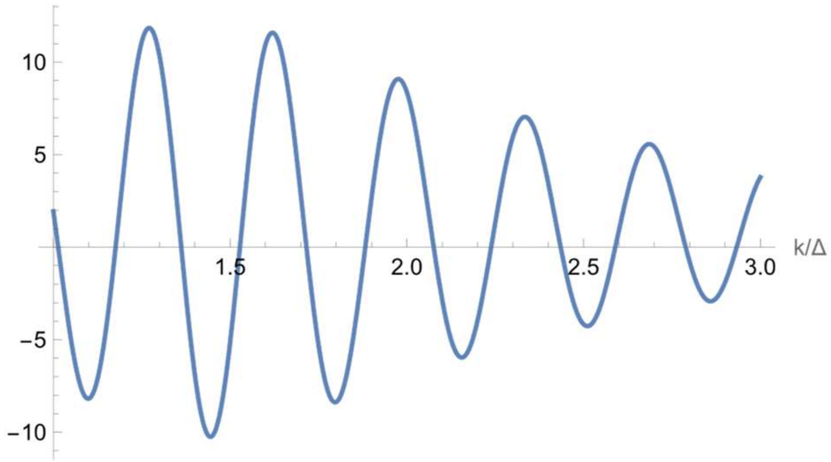
- Oscillations $T \sim f(\Delta)$
- Amplitude enhancement
- Equilateral peak
- The squeezed limit has only a climbing contribution (Strong dependence on the number of e-folds)

$1 + \langle \zeta\zeta\zeta \rangle_{corr} / \langle \zeta\zeta\zeta \rangle_{Maldacena}$ Equilateral $N = 60$

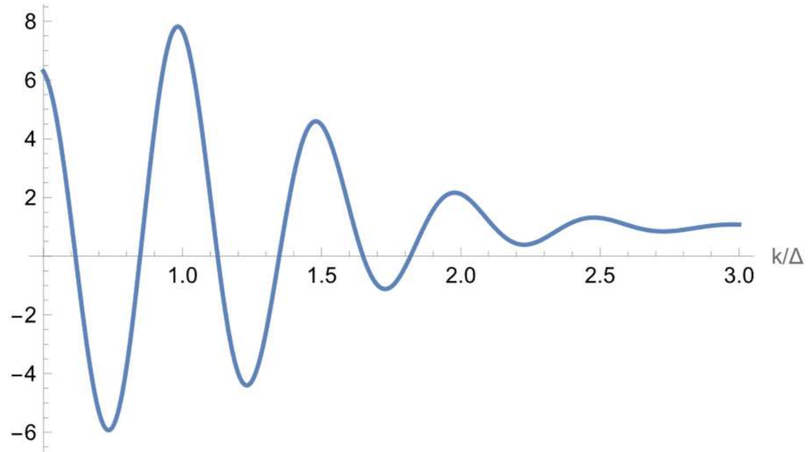


Non-Gaussian features

Equilateral $N = 65 - 66$



Squeezed (only climbing correction)
$N = 69 - 70$



Future prospects

- We are assuming that String Theory regulates the initial singularity. Can one do better?
- Comparison with data: possible since the result only depends on Δ, which was determined from the CMB angular power spectrum, and on the number N of e-folds
- Can this analysis be a benchmark for computations with more powerful tools? **Differential equations for cosmological correlators**, **Cosmological bootstrap**, etc
- Can this result be a guide to better understand different classes of cosmological correlators? **Loops in cosmological correlators**?

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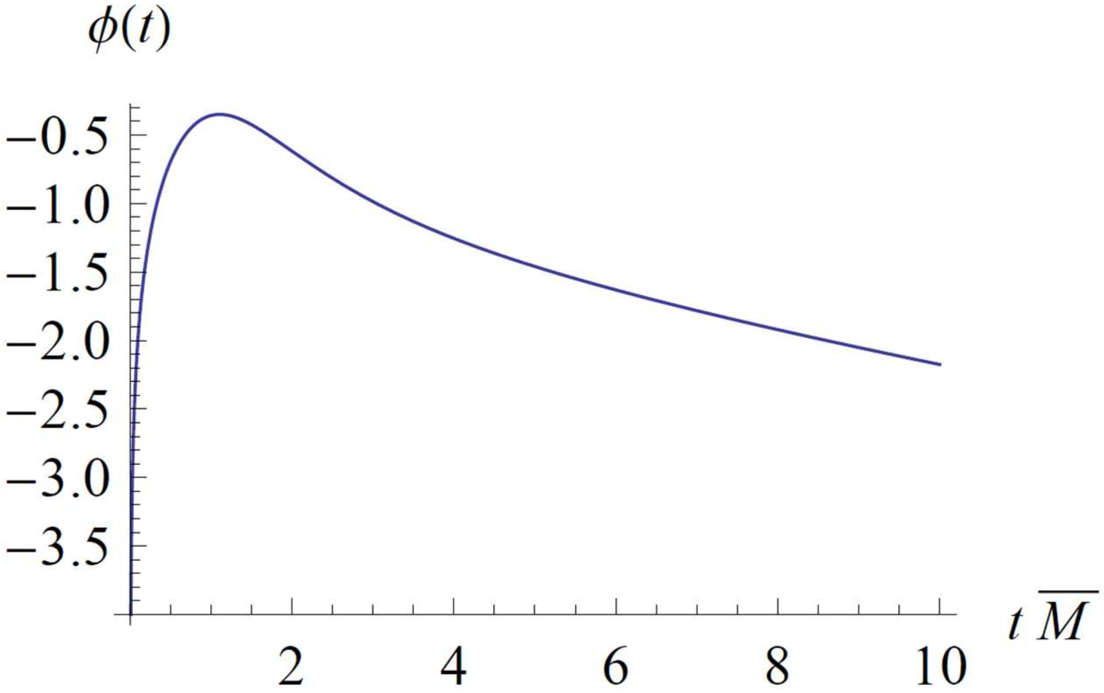
Thank you

Backup slides


$\phi(t)$
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
2
4
6
8
10
$t\,\overline{M}$

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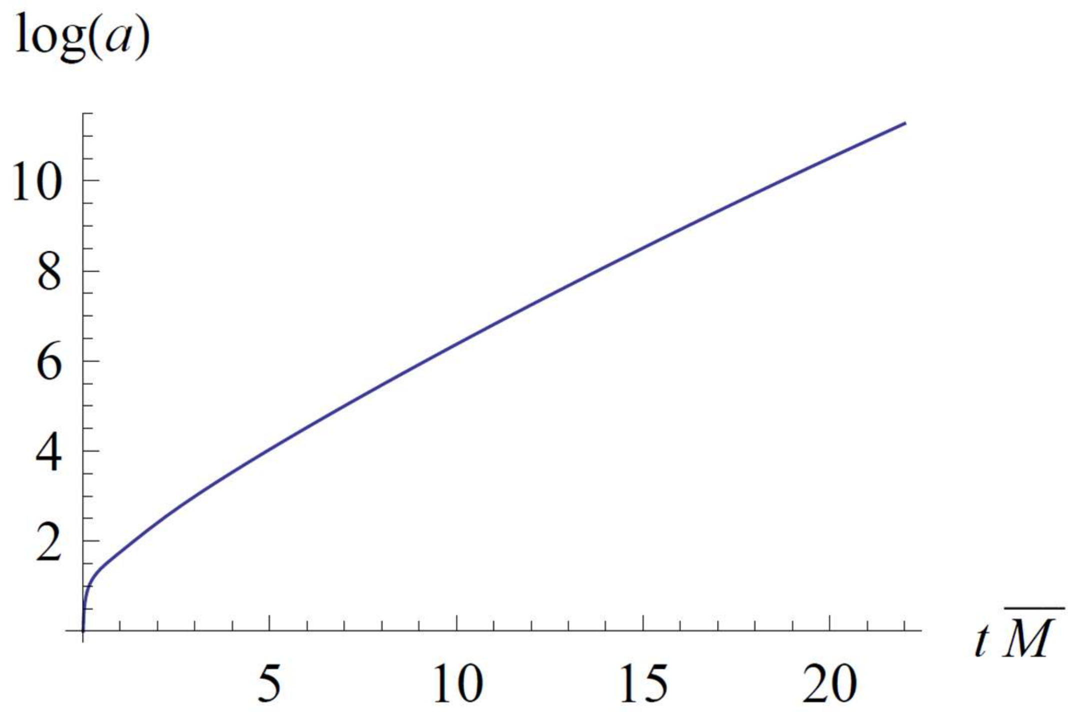

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