

OBSERVABLE GRAVITATIONAL WAVES FROM KINETICALLY MODIFIED NON-MCI

C. PALLIS

DEPARTAMENT DE FÍSICA TÈORICA – IFIC
UNIVERSITY OF VALÈNCIA – CSIC

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- C.P., *Phys. Rev. D* **91**, 123508 (2015) [arXiv:1503.05887].

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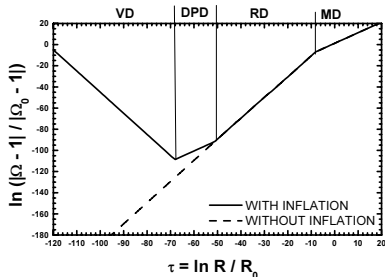
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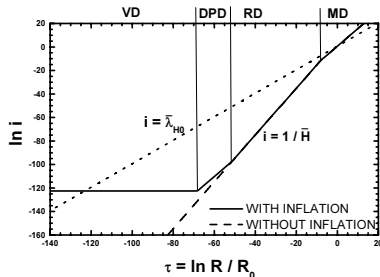
SHORTCOMINGS OF STANDARD BIG BANG (SBB)

• THE FLATNESS PROBLEM



GIVEN THAT $\Omega_0 = 1.02 \pm 0.02$ AND $\ln|\Omega - 1| \propto 6\tau$ [$\ln|\Omega - 1| \propto 4\tau$] FOR RD [MD], WE FIND $\Omega_{\text{BBN}} = 1 \pm 10^{-17}$ AND $\Omega_{\text{GUT}} = 1 \pm 10^{-54}$. THIS PUZZLE CAN BE RESOLVED IF WE HAD ONCE $d \ln|\Omega - 1|/d\tau < 0 \Leftrightarrow \dot{R} > 0$. INDEED, FOR VD $\ln|\Omega - 1| \propto -2\tau$ AND FOR $\Delta N \simeq 65$ WE FIND $\Omega_{\text{VD}} \sim 1 \pm 0.01$

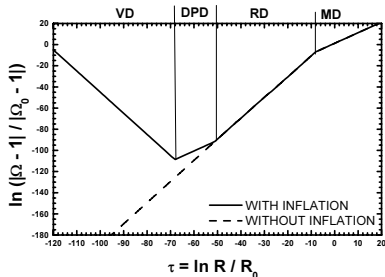
• THE HORIZON PROBLEM



A PHYSICAL LENGTH $\lambda = 2\pi R/k$ IS INSIDE HORIZON, $1/H$, IF $\lambda < 1/H \Leftrightarrow k > RH$. IF $\lambda_{H_0} = 1/H_0$ WE HAVE $\lambda_{H_0} > (1/\bar{H})$ FOR $\tau < 0$ SINCE $\ln \lambda \propto \tau$ AND $\ln(1/H) \propto 2\tau$ [$\ln(1/H) \propto 1.5\tau$] FOR RD [MD]. THIS PUZZLE CAN BE RESOLVED IF WE HAD ONCE $d \ln(1/H)/d\tau < 1 \Leftrightarrow \dot{R} > 0$. INDEED, FOR $H = \text{cst}$ AND $N_{H_0} \geq 50$ WE OBTAIN $\lambda < 1/H$.

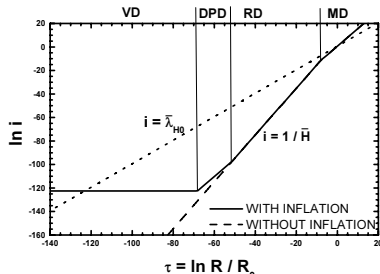
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• A PERIOD OF ACCELERATED EXPANSION OF THE UNIVERSE IS CALLED **INFLATION** AND CAN BE QUANTIFIED AS FOLLOWS:

$$\frac{\ddot{R}}{R} = (1 - \epsilon)H^2 = -\frac{1}{6}(1 + 3w)p > 0 \Leftrightarrow \begin{cases} \epsilon < 1 \\ w < -1/3 \end{cases} \quad \begin{array}{l} \text{WITH } \epsilon = -\dot{H}/H^2, \\ \text{WITH } w = P/\rho. \end{array} \quad (\text{WE USE } m_p = 1)$$

INFLATION AND THE INFLATON, $\sigma(t)$

- AN **HOMOGENEOUS** SCALAR FIELD $\sigma(t)$ HAS:
 - ENERGY DENSITY $\rho_\sigma = \frac{1}{2}\dot{\sigma}^2 + V(\sigma) \Rightarrow \dot{H} = -\dot{\sigma}^2/2,$
 - PRESSURE, $P_\sigma = \frac{1}{2}\dot{\sigma}^2 - V(\sigma).$

INFLATION THROUGH σ CAN BE ATTAINED IF: $\epsilon < 1 \Leftrightarrow \dot{\sigma} \ll V(\sigma) \Leftrightarrow P_\sigma = -\rho_\sigma$ ($w_\sigma = -1 < -1/3$)

$$\Leftrightarrow H^2 = \rho_\sigma/3 \simeq V/3 = \text{cst} \Rightarrow R(t) = R(t_i)e^{\Delta N_e} \text{ AND } T(t) = T(t_i)e^{-\Delta N_e},$$

WHERE $\Delta N_e = H(t - t_i)$ THE NUMBER OF e -FOLDINGS FOR $t > t_i$.

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- IF, IN ADDITION, WE HAVE: $3H\dot{\sigma} \gg \ddot{\sigma} \Leftrightarrow \eta < 1$, WITH $\eta = \frac{V_{,\sigma\sigma}}{3H^2}$ WHERE $_{,\sigma\sigma} = \frac{d^2}{d\sigma^2}$

THEN WE OBTAIN "SLOW ROLL" OF σ AND THE EQUATION OF MOTION OF σ

$$\ddot{\sigma} + 3H\dot{\sigma} + V_{,\sigma} = 0 \text{ BECOMES } -3H\dot{\sigma} = V_{,\sigma} \text{ WHERE } _{,\sigma} = \frac{d}{d\sigma}.$$

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- AS A CONSEQUENCE, THE NUMBER OF e -FOLDINGS THAT $k_\star = 0.05/\text{Mpc}$ SUFFERED DURING INFLATION IS

$$N_\star = \int_{\sigma_f}^{\sigma_\star} d\sigma \frac{V(\sigma)}{V_{,\sigma}}, \text{ WHERE:}$$

- $\sigma_\star$: THE VALUE OF σ WHEN THE SCALE $k_\star$ CROSSED OUTSIDE THE INFLATIONARY HORIZON
- σ_f : THE VALUE OF σ AT THE END OF INFLATION, WHICH CAN BE FOUND IN THE SLOW-ROLL APPROXIMATION FROM THE CONDITION:

$$Mc\{\epsilon(\sigma_f), |\eta(\sigma_f)|\} = 1, \text{ WITH } \epsilon \simeq \left(\frac{V_{,\sigma}}{V}\right)^2 \text{ AND } \eta \simeq \frac{V_{,\sigma\sigma}}{V}.$$

WHERE $Mc = \max [Mc = \min]$ IF σ DECREASES [INCREASES] DURING INFLATION – LARGE [SMALL]-FIELD MODELS.

- EXPANDING IN **FOURIER** SERIES THE PERTURBATION OF σ .

AND INSERTING INTO THE EQUATION OF MOTION OF σ , WE GET

- THE VACUUM TWO-POINT CORRELATION FUNCTION IS GIVEN BY

PRIMORDIAL CURVATURE PERTURBATION

- EXPANDING IN **FOURIER** SERIES THE PERTURBATION OF σ ,

$$\delta\sigma(\mathbf{x}, t) = \sigma(\mathbf{x}, t) - \sigma(t) = \int \frac{d^3\mathbf{k}}{(2\pi)^{3/2}} e^{i\mathbf{k}\mathbf{x}} \delta\sigma_{\mathbf{k}}(t)$$

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$$\delta\ddot{\sigma}_{\mathbf{k}} + 3H\delta\dot{\sigma}_{\mathbf{k}} + (k/R)^2 \delta\sigma_{\mathbf{k}} = 0 \Rightarrow$$

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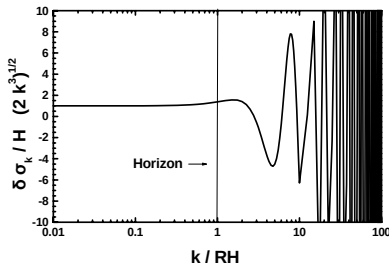
$$\langle 0 | \delta\sigma(\mathbf{x}, t) \delta\sigma(\mathbf{x}', t) | 0 \rangle = \int_0^\infty \frac{dk}{k} P_\sigma(k) e^{i\mathbf{k}(\mathbf{x}-\mathbf{x}')}$$

$$\text{WITH } A_\sigma^{1/2} = P_\sigma^{1/2}(k = k_\star) = \left(\frac{k^3}{2\pi^2} \right)^{1/2} \delta\sigma_{\mathbf{k}} \Big|_{k=k_\star=RH} = \frac{H_\star}{2\pi} \xrightarrow[\delta g_{\mu\nu}]{\delta T_{\mu\nu}} \begin{cases} A_s = A_\sigma^{1/2} H_\star / |\dot{\sigma}_\star| = H_\star^2 / 2\pi |\dot{\sigma}_\star|, \\ A_t = 8A_\sigma^{1/2} / m_{\text{p}}^2. \end{cases} \quad \text{WHERE}$$

$[A_\sigma, A_s, A_t]$ P_σ, P_s, P_t IS THE [AMPLITUDE] POWER SPECTRUM OF σ , CURVATURE (SCALAR) AND TENSOR PERTURBATION RESPECTIVELY.

- IN THE SLOW ROLL APPROXIMATION, WE CAN CORRELATE A_s WITH THE SHAPE OF $V(\phi)$ THROUGH THE FORMULA:

$$A_s^{1/2} = \frac{1}{2\sqrt{3}\pi} \frac{V(\sigma_\star)^{3/2}}{|V_{,\sigma}(\sigma_\star)|} \quad \text{AND} \quad A_t = r A_s \quad \text{WITH} \quad r = 16\epsilon(\sigma_\star).$$



PRIMORDIAL CURVATURE PERTURBATION

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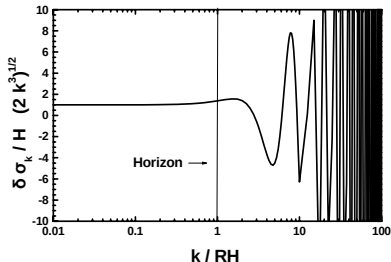
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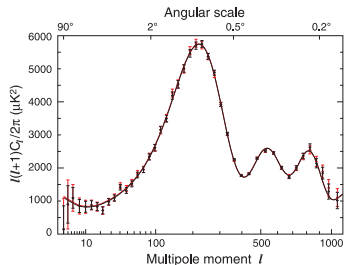
- THE SCALAR AND TENSOR SPECTRAL INDICES ARE DEFINED RESPECTIVELY AS:

$$n_s = 1 + \left. \frac{d \ln P_s}{d \ln k} \right|_{k=k_\star} = 1 - 6\epsilon(\sigma_\star) + 2\eta(\sigma_\star) \quad \text{AND} \quad n_t = 1 + \left. \frac{d \ln P_t}{d \ln k} \right|_{k=k_\star} = -2\epsilon(\sigma_\star)$$

- A_s IS DIRECTLY RELATED WITH THE MEASURED **QUADRUPOLE ANISOTROPY OF CMB**, $(\Delta T/T)_{\text{Q}} = A_s^{1/2} / 2\sqrt{15}$. ▶ ◀ ≡ ≡ ≡ ≡ ≡ ≡ ≡ ≡ ≡



OBSERVATIONS OF WMAP (2003, 2005, 2008, 2010) & PLANCK SATELLITES



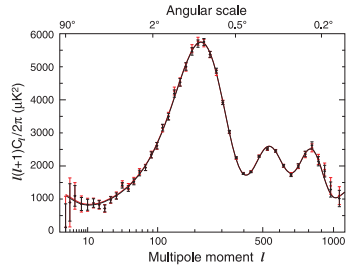
- $\Delta T/T$ CAN BE EXPANDED INTO A SERIES OF SPHERICAL HARMONICS, $Y_{\ell m}$:

$$\frac{\Delta T}{T} = \sum_{\ell=1}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} Y_{\ell m}(\theta, \phi) \quad \text{WITH} \quad \sum_m |a_{\ell m}|^2 \sim C_{\ell}$$

MEASURES THE ANISOTROPY BETWEEN 2 REGIONS WITH A DISTANCE ANGLE $\theta \sim 180^\circ/\ell$ USING A **GAUSSIAN** DISTRIBUTION.

PEAK	ℓ	INFORMATION
1ST	220	(A_s, Ω_0)
2ND	550	Ω_B
3RD	850	Ω_{CDM}

OBSERVATIONS OF WMAP (2003, 2005, 2008, 2010) & PLANCK SATELLITES



RESULTS OF THE ANALYSIS WITH Λ CDM MODEL

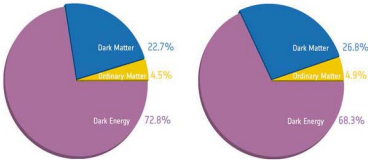
ENERGY-DENSITY DISTRIBUTION	
Ω_{DE}	$0.685^{+0.018}_{-0.016}$
$\Omega_{CDM}h^2$	0.1199 ± 0.0027
$\Omega_B h^2$	0.02205 ± 0.00028
INFLATIONARY OBSERVABLES	
n_s	0.968 ± 0.0045
$A_s^{1/2}$	$(4.627 \pm 0.01) \cdot 10^{-5}$

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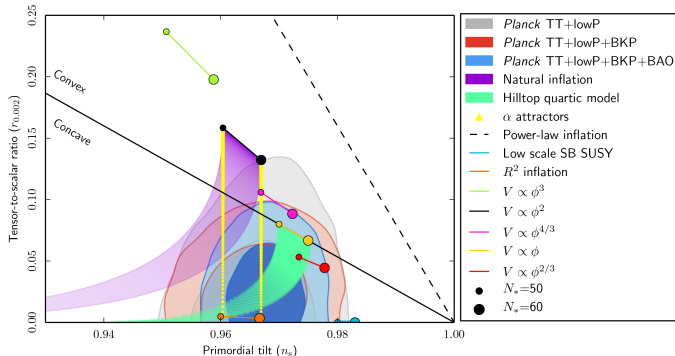
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Before Planck

After Planck

CONSTRAINTS FOR THE Λ CDM + r MODEL FROM BICEP2/Keck Array AND Planck 2015¹



- THE OBSERVABILITY OF **GRAVITATIONAL WAVES** IS BOUNDED AS FOLLOWS: $r \leq 0.12$ (r : TENSOR-TO-SCALAR RATIO).
- THE COMBINED BICEP2/Keck Array AND Planck RESULTS ALTHOUGH DO NOT EXCLUDE INFLATIONARY MODELS WITH NEGLIGIBLE r 'S, THEY SEEM TO FAVOR THOSE WITH r 'S OF ORDER 0.01 SINCE

$$r = 0.048^{+0.035}_{-0.032} \Rightarrow 0.01 \lesssim r \lesssim 0.085 \text{ AT 68\%C.L.}$$

- AS A CONSEQUENCE, THE SIMPLEST POWER-LAW MODELS BASED ON $V \propto \sigma^n$ ARE DISFAVORED FOR $n = 2$ OR EVEN EXCLUDED FOR $n = 4$.

¹ Planck Collaboration (2015); BICEP2/Keck Array and Planck Collaborations (2015)

COUPLING NON-MINIMALLY THE INFLATON TO GRAVITY

- OUR STARTING POINT IS THE ACTION IN THE **JORDAN FRAME (JF)** OF A SCALAR FIELD ϕ WITH POTENTIAL $V(\phi)$ NON-MINIMALLY COUPLED TO THE RICCI SCALAR CURVATURE, $\mathcal{R}$, THROUGH A FRAME FUNCTION $f_{\mathcal{R}}(\phi)$. THIS IS:

$$S = \int d^4x \sqrt{-g} \left(-\frac{1}{2} f_{\mathcal{R}}(\phi) \mathcal{R} + \frac{f_{\mathcal{K}}(\phi)}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - V(\phi) \right), \quad \text{WHERE}$$

$\mathfrak{g}$ IS THE DETERMINANT OF THE BACKGROUND METRIC AND $f_{\mathcal{R}}(\langle\phi\rangle) \simeq 1$ (IN REDUCED PLANCK UNITS WITH $m_{\text{P}} = 1$) TO GUARANTEE THE ORDINARY **EINSTEIN GRAVITY** AT LOW ENERGY. WE ALLOW FOR A KINETIC MIXING THROUGH THE FUNCTION $f_{\text{K}}(\phi)$.

²K. Maeda (1989); D.S. Salopek, J.R. Bond and J.M. Bardeen (1989); D.I. Kaiser (1995); T. Chiba and M. Yamaguchi (2008).

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- WE CAN WRITE S IN THE EINSTEIN FRAME (EF) AS FOLLOWS

$$\mathcal{S} = \int d^4x \sqrt{-\widehat{g}} \left(-\frac{1}{2} \widehat{\mathcal{R}} + \frac{1}{2} \widehat{g}^{\mu\nu} \partial_\mu \widehat{\phi} \partial_\nu \widehat{\phi} - \widehat{V}(\widehat{\phi}) \right)$$

PERFORMING A **CONFORMAL TRANSFORMATION**² ACCORDING WHICH WE DEFINE THE EF METRIC:

$$\widehat{g}_{\mu\nu} = f_R g_{\mu\nu} \Rightarrow \begin{cases} \sqrt{-\widehat{g}} = f_R^2 \sqrt{-g} \text{ AND } \widehat{g}^{\mu\nu} = g^{\mu\nu}/f_R, \\ \widehat{R} = (R + 3\Box \ln f_R + 3g^{\mu\nu}\partial_\mu f_R \partial_\nu f_R / 2f_R^2)/f_R \end{cases}$$

AND INTRODUCE THE **EF CANONICALLY NORMALIZED FIELD**, $\widehat{\phi}$, AND POTENTIAL, $\widehat{V}$, DEFINED AS FOLLOWS:

$$\left(\frac{d\widehat{\phi}}{d\phi}\right)^2 = J^2 = \frac{f_K}{f_R} + \frac{3}{2} \left(\frac{f_{R,\phi}}{f_R}\right)^2 \quad \text{AND} \quad \widehat{V}(\widehat{\phi}) = \frac{V(\widehat{\phi}(\phi))}{f_R(\widehat{\phi}(\phi))^2}.$$

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$$\left(\frac{d\widehat{\phi}}{d\phi} \right)^2 = J^2 = \frac{f_{\mathcal{K}}}{f_{\mathcal{R}}} + \frac{3}{2} \left(\frac{f_{\mathcal{R},\phi}}{f_{\mathcal{R}}} \right)^2 \quad \text{AND} \quad \widehat{V}(\widehat{\phi}) = \frac{V(\widehat{\phi}(\phi))}{f_{\mathcal{R}}(\widehat{\phi}(\phi))^2}.$$

- WE OBSERVE THAT $f_{\mathcal{R}}$ AFFECTS **BOTH** J AND $\widehat{V}_{\text{CI}}$. HERE WE DELIBERATE J FROM THE $f_{\mathcal{R}}$ -DEPENDENCE EMPLOYING $f_{\mathcal{K}} = c_{\mathcal{K}} f_{\mathcal{R}}^m$.
- THE ANALYSIS OF NON-MCI IN **THE EF** USING THE STANDARD SLOW-ROLL APPROXIMATION IS EQUIVALENT WITH **THE ANALYSIS IN JF**.

² K. Maeda (1989); D.S. Salopek, J.R. Bond and J.M. Bardeen (1989); D.I. Kaiser (1995); T. Chiba and M. Yamaguchi (2008).

INFLATIONARY OBSERVABLES - REQUIREMENTS

- THE **NUMBER OF E-FOLDINGS**, $\widehat{N}_\star$, THAT THE SCALE $k_S = 0.05/\text{Mpc}$ SUFFERS DURING NON-MCI HAS TO BE SUFFICIENT TO RESOLVE THE HORIZON AND FLATNESS PROBLEMS OF STANDARD BIG BANG:

$$\widehat{N}_\star = \int_{\widehat{\phi}_f}^{\widehat{\phi}_\star} d\widehat{\phi} \frac{\widehat{V}}{\widehat{V}_{,\widehat{\phi}}} = \int_{\phi_f}^{\phi_\star} d\phi J^2 \frac{\widehat{V}}{\widehat{V}_{,\phi}} \simeq 61.7 + \ln \frac{\widehat{V}(\phi_\star)^{1/2}}{\widehat{V}(\phi_f)^{1/3}} + \frac{1}{3} \ln T_{\text{rh}} + \frac{1}{2} \ln \frac{f_{\mathcal{R}}(\phi_\star)}{f_{\mathcal{R}}(\phi_f)^{1/3}}$$

WHERE $\phi_\star$ [$\widehat{\phi}_\star$] IS THE VALUE OF ϕ [$\widehat{\phi}$] WHEN $k_\star$ CROSSES OUTSIDE THE INFLATIONARY HORIZON;

ϕ_f [$\widehat{\phi}_f$] IS THE VALUE OF ϕ [$\widehat{\phi}$] AT THE END OF NON-MCI WHICH CAN BE FOUND FROM THE CONDITION

$$\max\{\widehat{\epsilon}(\phi_f), |\widehat{\eta}(\phi_f)|\} = 1, \quad \text{WITH} \quad \widehat{\epsilon} = \frac{1}{2} \left(\frac{\widehat{V}_{,\widehat{\phi}}}{\widehat{V}} \right)^2 = \frac{1}{2J^2} \left(\frac{\widehat{V}_{,\phi}}{\widehat{V}} \right)^2 \quad \text{AND} \quad \widehat{\eta} = \frac{\widehat{V}_{,\phi\phi}}{\widehat{V}} = \frac{1}{J^2} \left(\frac{\widehat{V}_{,\phi\phi}}{\widehat{V}} - \frac{\widehat{V}_{,\phi}}{\widehat{V}} \frac{J_{,\phi}}{J} \right).$$

³ Planck Collaboration (2015); BICEP2/Keck Array and Planck Collaborations (2015)

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- THE **AMPLITUDE OF THE POWER SPECTRUM** A_s OF THE CURVATURE PERTURBATIONS IS TO BE CONSISTENT WITH *Planck* DATA:

$$A_s^{1/2} = \frac{1}{2\sqrt{3}\pi} \frac{\widehat{V}(\widehat{\phi}_\star)^{3/2}}{|\widehat{V}_{,\widehat{\phi}}(\widehat{\phi}_\star)|} = \frac{|J(\phi_\star)|}{2\sqrt{3}\pi} \frac{\widehat{V}(\phi_\star)^{3/2}}{|\widehat{V}_{,\phi}(\phi_\star)|} = 4.627 \cdot 10^{-5}$$

³ *Planck Collaboration (2015); BICEP2/Keck Array and Planck Collaborations (2015)*

THE TWO REGIMES OF SYNERGISTIC NON-MCI

- NON-MCI HAS BEEN ORIGINALLY FORMULATED AS FOLLOWS: $V_{CI} = \lambda\phi^4/4$, WITH $f_R = 1 + c_R\phi^2$ AND $f_K = 1$.
- WE CAN GENERALIZE THE ABOVE CONSTRUCTION ESTABLISHING A SYNERGY BETWEEN f_R AND V_{CI} AS FOLLOWS⁴:

$$V_{CI}(\phi) = \lambda^2\phi^n/2^{n/2} \quad \text{WITH} \quad f_R = 1 + c_R\phi^{n/2} \quad \text{AND} \quad f_K = 1$$

⁴[C. Pallis \(2010\)](#); [R. Kallosh, A. Linde and D. Roest \(2013\)](#); [A. Kehagias, A.M. Dizgah and A. Riotto \(2013\)](#). □ ▶ ◀ ◻ ▶ ◀ ≡ ▶ ◀ ≡ ▶ ≡ ▶ ↺ 🔍 ↻

THE TWO REGIMES OF SYNERGISTIC NON-MCI

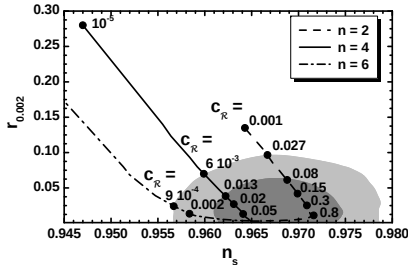
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- THE RESULTING MODEL EXHIBITS THE FOLLOWING **TWO REGIMES**:

- THE **WEAK** c_R REGIME, WITH $c_R \ll 1$ OR $\phi > 1$ AND c_R -DEPENDENT OBSERVABLES CONVERGING TOWARDS THEIR VALUES IN MCI, I.E., $n_s \simeq 1 - (2+n)/2\hat{N}_* = 0.963, 0.947$ AND $r \simeq 4n/\hat{N}_* \simeq 0.13, 0.28$ FOR $n = 2, 4$ RESPECTIVELY ($\hat{N}_* = 55$).
- THE **STRONG** c_R REGIME, WITH $c_R \gg 1$ AND $\phi < 1$ AND c_R -INDEPENDENT OBSERVABLES:

$$n_s \simeq 1 - 2/\hat{N}_* = 0.965 \quad \text{AND } r \simeq 12/\hat{N}_*^2 = 0.0036.$$



⁴ C. Pallis (2010); R. Kallosh, A. Linde and D. Roest (2013); A. Kehagias, A.M. Dizgah and A. Riotto (2013).

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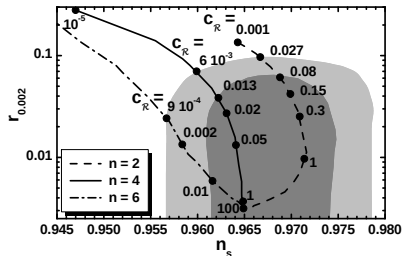
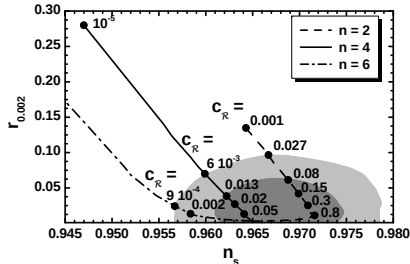
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- IN THE LATTER REGIME, THE MODELS FACE PROBLEMS WITH **PERTURBATIVE UNITARITY**.

⁴ C. Pallis (2010); R. Kallosh, A. Linde and D. Roest (2013); A. Kehagias, A.M. Dizgah and A. Riotto (2013).

MINIMAL VS. NON-MINIMAL INFLATION CHAOTIC BASED ON THE POWER-LAW POTENTIAL $V = \lambda^2 \phi^n / 2^{n/2}$

- If $f_R(\phi) = 1$, I.E., WITH **MINIMAL COUPLING** TO GRAVITY. WE FIND:

$$\epsilon \simeq \frac{n^2}{\phi^2} \quad \text{AND} \quad \eta \simeq -\frac{n(n-1)}{\phi^2}. \quad \text{THEREFORE} \quad \max\{\widehat{\epsilon}(\phi_f), |\widehat{\eta}(\phi_f)|\} = 1 \Rightarrow \phi_f \simeq \sqrt{2}n \quad \text{AND} \quad N_\star \simeq \frac{\phi_\star^2}{2n} \Rightarrow \phi_\star = \sqrt{2n\widehat{N}_\star} > 1.$$

$$A_s^{1/2} \simeq \lambda \phi_\star^{1+\frac{n}{2}} / 2^{1+\frac{n}{4}} n \sqrt{3}\pi = 4.627 \cdot 10^{-5} \Rightarrow \lambda \simeq \sqrt{6A_s} \pi n^{1-\frac{2+n}{4}} \widehat{N}_\star^{-\frac{n+2}{4}} \quad \text{E.G.} \quad \underline{\lambda \simeq 10^{-7}} \quad \text{FOR } n = 4.$$

$$n_s \simeq 1 - n + 2/2N_\star, \quad \alpha_s \simeq -2 + n/2N_\star^2 \quad \text{AND} \quad r \simeq 4n/N_\star. \quad \text{IN } \textcolor{red}{\textbf{TENSION}} \text{ WITH PLANCK DATA.}$$

- ♦ FOR $N_\star = 55$ AND $n = 2$ [4], WE FIND $n_s \simeq 0.963$ [0.947], $\alpha_s \simeq -6.5$ [-9.5] $\cdot 10^{-4}$ AND $r \simeq 0.13$ [0.28] > 0.12

- If $f_R(\phi) = 1 + c_R \phi^{n/2}$, I.E., WITH A **CONVENIENT NON-MINIMAL COUPLING** TO GRAVITY. FOR $c_R \gg 1$, WE FIND:

$$\widehat{V} = \frac{\lambda^2 \phi^n}{2^{n/2} f_R^2} \simeq \frac{\lambda^2}{2^{n/2} c_R^2}, \quad \widehat{\epsilon} \simeq \frac{4}{3c_R^2 \phi^n} \quad \text{AND} \quad \widehat{\eta} \simeq -\frac{4}{3f_R \phi^n}$$

$$\text{THEREFORE} \quad \max\{\widehat{\epsilon}(\phi_f), |\widehat{\eta}(\phi_f)|\} = 1 \Rightarrow \phi_f = (4/3c_R^2)^{1/n}$$

$$\text{ALSO} \quad \widehat{N}_\star \simeq 3c_R \phi_\star^{n/2} / 4 \Rightarrow \phi_\star = (4\widehat{N}_\star / 3c_R)^{2/n}.$$

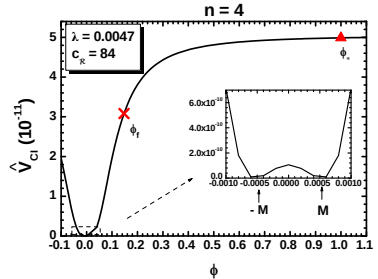
$$\text{AND} \quad A_s^{1/2} \simeq 2^{-\frac{5}{2} + \frac{n}{4}} \lambda \widehat{N}_\star^{n/2} / \pi f_R \Rightarrow \underline{\lambda = 3 \cdot 2^{n/4} \sqrt{2A_s} \pi c_R / \widehat{N}_\star}$$

E.G., FOR $n = 4$ AND $\widehat{N}_\star \simeq 55$ WE GET

$$\phi \leq 1 \Rightarrow \underline{c_R \gtrsim 4\widehat{N}_\star/3 \simeq 74}, \quad \text{AND} \quad \underline{c_R \simeq 41850 \lambda}.$$

- ♦ **ATTRACTOR** (INDEPENDENT OF n AND c_R) **VALUES** :

$$n_s \simeq 1 - 2/\widehat{N}_\star \simeq 0.965, \quad \alpha_s \simeq -2/\widehat{N}_\star^2 \simeq -6.4 \cdot 10^{-4} \quad r \simeq 12/\widehat{N}_\star \simeq 4 \cdot 10^{-3} \quad \textcolor{red}{\textbf{IN AGREEMENT WITH Planck.}}$$



EINSTEIN FRAME COMPUTATION

- WE ANALYZE THE SMALL-FIELD BEHAVIOR⁵ OF THE THEORY EXPANDING S ABOUT $\langle\phi\rangle = 0$ IN TERMS OF $\widehat{\phi}$. TO THIS END WE FIND $\langle J\rangle$

$$J^2 = \left(\frac{d\widehat{\phi}}{d\phi}\right)^2 = \frac{f_K}{f_R} + \frac{3n^2 c_R^2 \phi^{n-2}}{8f_R^2} \Rightarrow \langle J\rangle = \begin{cases} \sqrt{3/2}c_R, & \text{FOR } n = 2, \\ 1, & \text{FOR } n \neq 2 \end{cases} \quad \text{FOR } \langle f_K\rangle = 1.$$

WE OBSERVE THAT $\widehat{\phi} = \phi$ FOR $n > 2$ **AT THE VACUUM** OF THE THEORY.

⁵J.L.F. Barbon and J.R. Espinosa (2009); C.P. Burgess, H.M. Lee, and M. Trott (2010); A. Kehagias, A.M. Dizgah, and A. Riotto (2013) ◀ ≡ ▶ ≡ ↺ ↻

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$$J^2 \dot{\phi}^2 = \left(1 - \sqrt{\frac{8}{3}}\widehat{\phi} + 2\widehat{\phi}^2 - \dots\right) \dot{\widehat{\phi}}^2 \quad \text{AND} \quad \widehat{V} = \frac{\lambda^2 \widehat{\phi}^2}{3c_{\mathcal{R}}^2} \left(1 - \sqrt{\frac{8}{3}}\widehat{\phi} + 2\widehat{\phi}^2 - \dots\right).$$

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- **FOR $n > 2$** SIMILAR EXPANSIONS ARE c_R DEPENDENT:

$$J^2 \dot{\phi}^2 = \left(1 - c_R \widehat{\phi}^{\frac{n}{2}} + \frac{3n^2}{8} c_R^2 \widehat{\phi}^{n-2} + c_R^2 \widehat{\phi}^n \dots \right) \dot{\widehat{\phi}}^2 \quad \text{AND} \quad \widehat{V}_{CI} = \frac{\lambda^2 \widehat{\phi}^n}{2} \left(1 - 2c_R \widehat{\phi}^{\frac{n}{2}} + 3c_R^2 \widehat{\phi}^n - 4c_R^3 \widehat{\phi}^{\frac{3n}{2}} + \dots \right).$$

SINCE THE TERM WHICH YIELDS THE SMALLEST DENOMINATOR FOR $c_R > 1$ IS $3n^2 c_R^2 \widehat{\phi}^{n-2}/8$ WE FIND $\Lambda_{UV} = m_P / c_R^{2/(n-2)} \ll m_P$.

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- IF WE INTRODUCE **A NON-CANONICAL KINETIC MIXING** SUCH THAT

$$\langle f_K \rangle = c_K \quad \text{AND} \quad c_R = r_{RK} c_K^{n/4}$$

THE EXPANSIONS ABOVE ARE REWRITTEN IN TERMS OF THE NEW PARAMETER r_{RK}

$$J^2 \dot{\phi}^2 = \left(1 - r_{RK} \widehat{\phi}^{\frac{n}{2}} + \frac{3n^2}{8} r_{RK}^2 \widehat{\phi}^{n-2} + r_{RK}^2 \widehat{\phi}^n \dots \right) \dot{\widehat{\phi}}^2 \quad \text{AND} \quad \widehat{V}_{CI} = \frac{\lambda^2 \widehat{\phi}^n}{2c_K^{n/2}} \left(1 - 2r_{RK} \widehat{\phi}^{\frac{n}{2}} + 3r_{RK}^2 \widehat{\phi}^n - 4r_{RK}^3 \widehat{\phi}^{\frac{3n}{2}} + \dots \right).$$

CONSEQUENTLY, **NO PROBLEM** WITH THE PERTURBATIVE UNITARITY EMERGES FOR $r_{RK} \leq 1$, EVEN IF c_R AND c_K ARE LARGE.

⁵ J.L.F. Barbon and J.R. Espinosa (2009); C.P. Burgess, H.M. Lee, and M. Trott (2010); A. Kehagias, A.M. Dizgah, and A. Riotto (2013) ◀ ≡ ▶ ≡ 🔍 ↺

JORDAN FRAME COMPUTATION

- IF WE EXPAND $g_{\mu\nu}$ ABOUT THE FLAT SPACETIME METRIC $\eta_{\mu\nu}$ AND ϕ ABOUT ITS V.E.V AS FOLLOWS

$$g_{\mu\nu} \simeq \eta_{\mu\nu} + h_{\mu\nu} \quad \text{AND} \quad \phi = \langle \phi \rangle + \delta\phi \quad \text{WHERE} \quad \langle \phi \rangle \simeq 0.$$

THE LAGRANGIAN CORRESPONDING TO THE TWO FIRST TERMS IN THE RIGHT-HAND SIDE OF S TAKES THE FORM ($\langle \phi \rangle = 0$):

$$\begin{aligned} \delta\mathcal{L} &= -\frac{\langle f_{\mathcal{R}} \rangle}{4} F_{\text{EH}}(h^{\mu\nu}) + \frac{\langle f_{\mathcal{K}} \rangle}{2} \partial_\mu \delta\phi \partial^\mu \delta\phi + \left(\langle f_{\mathcal{R},\phi} \rangle \delta\phi + \frac{1}{2} \langle f_{\mathcal{R},\phi\phi} \rangle \delta\phi^2 + \frac{1}{6} \langle f_{\mathcal{R},\phi\phi\phi} \rangle \delta\phi^3 + \dots \right) F_{\mathcal{R}} \\ &= -\frac{1}{8} F_{\text{EH}}(\bar{h}^{\mu\nu}) + \frac{1}{2} \partial_\mu \bar{\delta\phi} \partial^\mu \bar{\delta\phi} + \Lambda_{UV}^{-1} \bar{\delta\phi}^{n/2} \square \bar{h}, \quad \left(\text{THE ONLY NON-VANISHING TERM IS } (n/2)! c_{\mathcal{R}} \delta\phi^{n/2} \right) \end{aligned}$$

WHERE THE F_{EH} AND $F_{\mathcal{R}}$ READ: $F_{\text{EH}} = h^{\mu\nu} \square h_{\mu\nu} - h \square h + 2 \partial_\rho h^{\mu\rho} \partial^\nu h_{\mu\nu} - 2 \partial_\nu h^{\mu\nu} \partial_\mu h$ AND $F_{\mathcal{R}} = \square h - \partial_\mu \partial_\nu h^{\mu\nu}$ WITH $h = h_\mu^\mu$.

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- THE **JF CANONICALLY NORMALIZED FIELDS** $\bar{h}_{\mu\nu}$ AND $\bar{\delta\phi}$ ARE DEFINED BY THE RELATIONS:

$$\bar{\delta\phi} = \sqrt{\frac{\langle \bar{f}_{\mathcal{R}} \rangle}{\langle f_{\mathcal{R}} \rangle}} \delta\phi \quad \text{AND} \quad \bar{h}_{\mu\nu} = \sqrt{\langle f_{\mathcal{R}} \rangle} h_{\mu\nu} + \frac{\langle f_{\mathcal{R},\phi} \rangle}{\sqrt{\langle f_{\mathcal{R}} \rangle}} \eta_{\mu\nu} \delta\phi \quad \text{WHERE} \quad \bar{f}_{\mathcal{R}} = f_{\mathcal{K}} f_{\mathcal{R}} + \frac{3}{2} f_{\mathcal{R},\phi}^2 \quad \text{WITH} \quad \langle f_{\mathcal{R}} \rangle = 1 \quad \text{AND} \quad \langle f_{\mathcal{R},\phi} \rangle = 0 \quad \text{FOR } n > 2.$$

- FOR $n = 2$, NO OFFENDING TERM ARISES AND SO IT IS A **UNITARITY-SAFE** CASE.
- THE **PROBLEMATIC SCATTERING AMPLITUDE** $\mathcal{A}$ REMAINS WITHIN THE VALIDITY OF THE PERTURBATION THEORY PROVIDED THAT $E < \Lambda_{UV}$ IS WRITTEN IN TERMS OF THE CENTER-OF-MASS ENERGY E AS FOLLOWS

$$\mathcal{A} \sim \left(\frac{E}{\Lambda_{UV}} \right)^2 \quad \text{WITH} \quad \Lambda_{UV} \simeq \frac{1}{c_{\mathcal{R}}} \frac{\langle \bar{f}_{\mathcal{R}} \rangle^{n/4}}{\langle f_{\mathcal{R}} \rangle^{(n-2)/4}} = \frac{\langle f_{\mathcal{K}} \rangle^{n/4}}{c_{\mathcal{R}}} = r_{\mathcal{RK}}^{-1} \quad \text{IF} \quad \langle f_{\mathcal{K}} \rangle = c_{\mathcal{K}} = (c_{\mathcal{R}}/r_{\mathcal{RK}})^{4/n}$$

THEREFORE, WE VERIFY THAT PERTURBATIVE UNITARITY IS RETAINED UP TO PLANCK SCALE, IF $r_{\mathcal{RK}} \leq 1$. FOR THESE REASONS

JORDAN FRAME COMPUTATION

- IF WE EXPAND $g_{\mu\nu}$ ABOUT THE FLAT SPACETIME METRIC $\eta_{\mu\nu}$ AND ϕ ABOUT ITS V.E.V AS FOLLOWS

$$g_{\mu\nu} \simeq \eta_{\mu\nu} + h_{\mu\nu} \quad \text{AND} \quad \phi = \langle \phi \rangle + \delta\phi \quad \text{WHERE} \quad \langle \phi \rangle \simeq 0.$$

THE LAGRANGIAN CORRESPONDING TO THE TWO FIRST TERMS IN THE RIGHT-HAND SIDE OF S TAKES THE FORM ($\langle \phi \rangle = 0$):

$$\begin{aligned} \delta\mathcal{L} &= -\frac{\langle f_{\mathcal{R}} \rangle}{4} F_{\text{EH}}(h^{\mu\nu}) + \frac{\langle f_{\mathcal{K}} \rangle}{2} \partial_\mu \delta\phi \partial^\mu \delta\phi + \left(\langle f_{\mathcal{R},\phi} \rangle \delta\phi + \frac{1}{2} \langle f_{\mathcal{R},\phi\phi} \rangle \delta\phi^2 + \frac{1}{6} \langle f_{\mathcal{R},\phi\phi\phi} \rangle \delta\phi^3 + \dots \right) F_{\mathcal{R}} \\ &= -\frac{1}{8} F_{\text{EH}}(\bar{h}^{\mu\nu}) + \frac{1}{2} \partial_\mu \bar{\delta\phi} \partial^\mu \bar{\delta\phi} + \Lambda_{UV}^{-1} \bar{\delta\phi}^{n/2} \square \bar{h}, \quad (\text{THE ONLY NON-VANISHING TERM IS } (n/2)! c_{\mathcal{R}} \delta\phi^{n/2}) \end{aligned}$$

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WE PROPOSE TO ANALYZE MODELS OF **KINETICALLY MODIFIED non-MCI** WITH $f_{\mathcal{K}} = c_{\mathcal{K}} f_{\mathcal{R}}^m$ WHERE $c_{\mathcal{K}} = (c_{\mathcal{R}}/r_{\mathcal{RK}})^{4/n}$ & $r_{\mathcal{RK}} \leq 1$

(SINCE $\langle f_{\mathcal{K}} \rangle = c_{\mathcal{K}}$ & $\langle f_{\mathcal{R}} \rangle = 1$ AND THE EXTRA FUNCTIONAL UNCERTAINTY IS PARAMETERIZED BY $f_{\mathcal{R}}^m$)

REALIZATION OF NON-MCI WITHIN SUGRA (USING A GAUGE SINGLET INFLATON)

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$$S = \int d^4x \sqrt{-\widehat{g}} \left(-\frac{1}{2} \widehat{\mathcal{R}} + K_{\alpha\bar{\beta}} \widehat{g}^{\mu\nu} \partial_\mu \Phi^\alpha \partial_\nu \Phi^{*\bar{\beta}} - \widehat{V} \right) \quad \text{WHERE} \quad \widehat{V} = \widehat{V}_F = e^K \left(K^{\alpha\bar{\beta}} (D_\alpha W) (D_{\bar{\beta}}^* W^*) - 3|W|^2 \right),$$

K IS THE KÄHLER POTENTIAL WITH $K_{\alpha\bar{\beta}} = \frac{\partial^2 K}{\partial \Phi^\alpha \partial \Phi^{*\bar{\beta}}} > 0$ AND $K^{\alpha\bar{\beta}} K_{\alpha\bar{\gamma}} = \delta_{\bar{\gamma}}^{\bar{\beta}}$; $D_\alpha W = W_{,\Phi^\alpha} + K_{,\Phi^\alpha} W$.

THEREFORE, IMPLEMENTING NON-MCI WITHIN SUGRA REQUIRES THE APPROPRIATE SELECTION OF W AND K

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SELECTING CONVENIENTLY THE SUPERPOTENTIAL AND FRAME FUNCTION

- WE USE 2 SUPERFIELDS $\Phi^1 = \Phi$ (**INFLATON**) AND $\Phi^2 = S$ (**“STABILIZER” FIELD**) AND ADOPT THE FOLLOWING SUPERPOTENTIAL:

$$W = \lambda S \Phi^{n/2}$$

FROM WHICH IN THE THE SUSY LIMIT WE GET $V_{CI} = \lambda^2 |\Phi|^n + \lambda^2 |S|^2$

CHARGE ASSIGNMENTS

SUPERFIELDS:	S	Φ
$U(1)$	1	$2/n$
$U(1)_R$	1	0

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OR, IF WE DO NOT INSIST ON THE PURELY LOGARITHMIC KÄHLER POTENTIAL :

$$K_2 = -3 \ln \left(\frac{1}{2} (F_{\mathcal{R}} + F_{\mathcal{R}}^*) - F_S \right) - \frac{c_K}{2^m} (F_{\mathcal{R}} + F_{\mathcal{R}}^*)^{m-1} F_K,$$

WHERE WE DEFINE THE FUNCTIONS WHICH PROVIDE THE NON-MINIMAL COUPLING TO GRAVITY AND THE KINETIC TERMS OF Φ AND S

$$F_{\mathcal{R}}(\Phi) = 1 + 2^{\frac{n}{4}} \Phi^{\frac{n}{2}} c_{\mathcal{R}}, \quad F_K = (\Phi - \Phi^*)^2 \quad \text{AND} \quad F_S = |S|^2/3 - k_S |S|^4/3.$$

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- FOR $c_K \gg c_{\mathcal{R}}$, OUR MODELS ARE COMPLETELY **NATURAL**, BECAUSE THE THEORY ENJOYS THE FOLLOWING ENHANCED SYMMETRIES:

$$\Phi \rightarrow \Phi^*, \quad \Phi \rightarrow \Phi + c \quad (c \in \mathbb{R}) \quad \text{AND} \quad S \rightarrow e^{i\alpha} S, \quad \text{IN THE LIMITS} \quad c_{\mathcal{R}} \rightarrow 0 \quad \& \quad \lambda \rightarrow 0$$

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OR, IF WE DO NOT INSIST ON THE PURELY LOGARITHMIC KÄHLER POTENTIAL :

$$K_2 = -3 \ln \left(\frac{1}{2} (F_{\mathcal{R}} + F_{\mathcal{R}}^*) - F_S \right) - \frac{c_K}{2m} (F_{\mathcal{R}} + F_{\mathcal{R}}^*)^{m-1} F_K,$$

WHERE WE DEFINE THE FUNCTIONS WHICH PROVIDE THE NON-MINIMAL COUPLING TO GRAVITY AND THE KINETIC TERMS OF Φ AND S

$$F_{\mathcal{R}}(\Phi) = 1 + 2^{\frac{n}{4}} \Phi^{\frac{n}{2}} c_{\mathcal{R}}, \quad F_K = (\Phi - \Phi^*)^2 \quad \text{AND} \quad F_S = |S|^2/3 - k_S |S|^4/3.$$

- FOR $c_K \gg c_{\mathcal{R}}$, OUR MODELS ARE COMPLETELY **NATURAL**, BECAUSE THE THEORY ENJOYS THE FOLLOWING ENHANCED SYMMETRIES:

$$\Phi \rightarrow \Phi^*, \quad \Phi \rightarrow \Phi + c \quad (c \in \mathbb{R}) \quad \text{AND} \quad S \rightarrow e^{i\alpha} S, \quad \text{IN THE LIMITS} \quad c_{\mathcal{R}} \rightarrow 0 \quad \& \quad \lambda \rightarrow 0$$

- ALONG THE **INFLATIONARY DIRECTION** $S = \Phi - \Phi^* = 0$, $\widehat{V}_{\text{CI}}$ THE **ONLY SURVIVING TERM** OF $\widehat{V}$ IS:

$$\widehat{V}_{\text{CI}} = e^K K^{SS^*} |W_{,S}|^2 = \frac{\lambda^2 |\Phi|^n}{f_{\mathcal{R}}^2} \quad \text{WHERE} \quad f_{\mathcal{R}} = F_{\mathcal{R}} = -\Omega/3, \quad \text{SINCE} \quad e^K = f_{\mathcal{R}}^{-3} \quad \text{AND} \quad K^{SS^*} = f_{\mathcal{R}}.$$

- THE FUNCTION $c_K f_{\mathcal{R}}^m$ REMAINS **INVISIBLE** IN $\widehat{V}_{\text{CI}}$ AND INFLUENCES ONLY THE CANONICAL NORMALIZATION OF Φ , $K_{\Phi\Phi^*} = J^2$

SELECTING CONVENIENTLY THE SUPERPOTENTIAL AND FRAME FUNCTION

- WE USE 2 SUPERFIELDS $\Phi^1 = \Phi$ (**INFLATON**) AND $\Phi^2 = S$ (**"STABILIZER" FIELD**) AND ADOPT THE FOLLOWING SUPERPOTENTIAL:

$$W = \lambda S \Phi^{n/2}$$

FROM WHICH IN THE THE SUSY LIMIT WE GET $V_{\text{CI}} = \lambda^2 |\Phi|^n + \lambda^2 |S|^2$

- TO OBTAIN **KINETICALLY MODIFIED NON-MCI IN SUGRA** WE SELECT THE FOLLOWING KÄHLER POTENTIAL K :

$$K_1 = -3 \ln \left(\frac{1}{2} (F_{\mathcal{R}} + F_{\mathcal{R}}^*) + \frac{c_K}{2m6} (F_{\mathcal{R}} + F_{\mathcal{R}}^*)^m F_K - F_S + \frac{k_{\Phi}}{6} F_K^2 - \frac{k_S \Phi}{3} F_K |S|^2 \right),$$

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- THE **η PROBLEM** WITHIN SUGRA IS RESOLVED BY MILDLY TUNING $c_K \gg 1$ AND $r_{\mathcal{R}K} = c_{\mathcal{R}}/c_K^{n/4} \leq 1$,

CHARGE ASSIGNMENTS

SUPERFIELDS:	S	Φ
$U(1)$	1	$2/n$
$U(1)_R$	1	0

FRAMEWORK OF INFLATIONARY ANALYSIS

- EXPANDING Φ AND S IN REAL AND IMAGINARY PARTS AS FOLLOWS:

$$\Phi = \phi e^{i\theta} / \sqrt{2} \quad \text{AND} \quad S = (s + i\bar{s}) / \sqrt{2} \quad \text{WE OBTAIN} \quad \widehat{V}_{\text{CI}} = \lambda^2 \phi^n / (1 + c_{\mathcal{R}} \phi^{n/2})^2 \quad (\text{NO DEPENDENCE ON } m \text{ AND } c_K \text{ ARISES})$$

- WE CAN CHECK THE STABILITY OF THE INFLATIONARY TRAJECTORY $s = \bar{s} = \theta = 0$ W.R.T THE FLUCTUATIONS OF THE VARIOUS FIELDS, I.E.

$$\left. \frac{\partial V}{\partial \chi^\alpha} \right|_{s=\bar{s}=\theta=0} = 0 \quad \text{AND} \quad \widehat{m}_{\chi^\alpha}^2 > 0 \quad \text{WHERE} \quad \widehat{m}_{\chi^\alpha}^2 = \text{EGV} [\widehat{M}_{\alpha\beta}^2] \quad \text{WITH} \quad \widehat{M}_{\alpha\beta}^2 = \left. \frac{\partial^2 V}{\partial \chi^\alpha \partial \chi^\beta} \right|_{\theta=s=\bar{s}=0} \quad \text{AND} \quad \chi^\alpha = \theta, s, \bar{s}.$$

- HERE WE INTRODUCE THE **EF CANONICALLY NORMALIZED FIELDS**, $d\widehat{\phi}/d\phi = J \simeq \sqrt{c_K} f_{\mathcal{R}}^{m-1}$, $\widehat{\theta} \simeq J\phi\theta$ AND $(\widehat{s}, \widehat{\bar{s}}) \simeq (s, \bar{s}) / \sqrt{f_{\mathcal{R}}}$.

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THE MASS SPECTRUM ALONG THE INFLATIONARY TRAJECTORY – $n_\theta = 4$ [$n_\theta = 6$] FOR $K = K_1$ [$K = K_2$].

FIELDS	EINGESTATES	MASSSES SQUARED
1 REAL SCALAR	$\widehat{\theta}$	$\widehat{m}_\theta^2 \simeq n_\theta \widehat{V}_{\text{CI}} / 3 \simeq n_\theta H_{\text{CI}}^2$
2 REAL SCALARS	$\widehat{s}, \widehat{\bar{s}}$	$\widehat{m}_s^2 \simeq 2(6k_S f_{\mathcal{R}} - 1) \widehat{V}_{\text{CI}} / 3$
2 WEYL SPINORS	$\widehat{\psi}_\pm = (\widehat{\psi}_\Phi \pm \widehat{\psi}_S) / \sqrt{2}$	$\widehat{m}_{\psi_\pm}^2 \simeq n^2 \widehat{V}_{\text{CI}} / 2c_{\mathcal{K}} \phi^2 f_{\mathcal{R}}^{1+m}$

- $\forall \alpha, \widehat{m}_{\chi^\alpha}^2 > 0$. ESPECIALLY $\widehat{m}_s^2 > 0 \Leftrightarrow k_S > (0.5 - 1.5)$;
- $\forall \alpha, \widehat{m}_{\chi^\alpha}^2 > \widehat{H}_{\text{CI}}^2$ AND SO ANY INFLATIONARY PERTURBATIONS OF THE FIELDS OTHER THAN THE INFLATON ARE SAFELY ELIMINATED;
- THE ONE-LOOP **RADIATIVE CORRECTIONS** (RCs) À LA COLEMAN-WEINBERG TO $\widehat{V}_{\text{CI}}$ HAVE THE USUAL FORM:

$$\Delta \widehat{V}_{\text{CI}} = \frac{1}{64\pi^2} \left(\widehat{m}_\theta^4 \ln \frac{\widehat{m}_\theta^2}{\Lambda^2} + 2\widehat{m}_s^4 \ln \frac{\widehat{m}_s^2}{\Lambda^2} - 4\widehat{m}_{\psi_\pm}^4 \ln \frac{\widehat{m}_{\psi_\pm}^2}{\Lambda^2} \right)$$

WHERE $\Lambda \simeq (1 - 5) \cdot 10^{14}$ IS A RENORMALIZATION GROUP MASS SCALE DETERMINED BY REQUIRING $\Delta \widehat{V}_{\text{CI}}(\phi_\star) = 0$ OR $\Delta \widehat{V}_{\text{CI}}(\phi_f) = 0$. UNDER THESE CIRCUMSTANCES, $\Delta \widehat{V}_{\text{CI}}$ HAS **NO SIGNIFICANT EFFECT** ON THE RESULTS.

APPROXIMATING THE INFLATIONARY DYNAMICS

- THE SLOW-ROLL PARAMETERS ARE DETERMINED USING THE STANDARD FORMULAE IN THE EF:

$$\widehat{\epsilon} = n^2 / (2\phi^2 c_K f_{\mathcal{R}}^{1+m}) \quad \text{AND} \quad \widehat{\eta} = \left(2(1 - 1/n) - (4 + n(1 + m)c_K \phi^{\frac{n}{2}} / 2n) \right) \widehat{\epsilon}.$$

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- THE NUMBER OF e -FOLDINGS IS CALCULATED TO BE

$$\widehat{N}_{\star} \simeq \frac{c_K \phi_{\star}^2}{2n} {}_2F_1 \left(-m, \frac{4}{n}; 1 + \frac{4}{n}; -c_{\mathcal{R}} \phi_{\star}^{n/2} \right) \Rightarrow \phi_{\star} \simeq \begin{cases} \sqrt{\frac{2n\widehat{N}_{\star}}{c_K}} & \text{FOR } m = 0, \text{ SINCE } {}_2F_1 \left(0, \frac{4}{n}; 1 + \frac{4}{n}; -c_{\mathcal{R}} \phi_{\star}^{n/2} \right) = 1; \\ \sqrt{\frac{f_{m\star}-1}{r_{\mathcal{R}K} c_K}} & \text{FOR } n = 4, \text{ SINCE } {}_2F_1 \left(-m, 1; 2; -c_{\mathcal{R}} \phi_{\star}^{n/2} \right) = \frac{f_{\mathcal{R}}^{1+m}-1}{(1+m)c_{\mathcal{R}}\phi_{\star}^2}. \end{cases}$$

HERE ${}_2F_1$ IS THE GAUSS HYPERGEOMETRIC FUNCTION AND $f_{m\star} = (1 + 8(m + 1)r_{\mathcal{R}K}\widehat{N}_{\star})^{1/(1+m)}$.

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- FOR EVERY m AND n , THERE IS A LOWER BOUND ON c_K , ABOVE WHICH $\phi_{\star} < 1$.
- THE POWER SPECTRUM NORMALIZATION IMPLIES A **DEPENDENCE OF λ ON c_K** FOR EVERY $r_{\mathcal{RK}}$

$$\lambda = \sqrt{3A_s\pi} \cdot \begin{cases} (c_K/n\widehat{N}_{\star})^{\frac{n}{4}} (2nf_{n\star}/\widehat{N}_{\star})^{\frac{1}{2}} & \text{FOR } m = 0, \\ 16c_K r_{\mathcal{RK}}^{3/2} / (f_{m\star} - 1)^{\frac{3}{2}} f_{m\star}^{\frac{1+m}{2}} & \text{FOR } n = 4, \end{cases} \quad \text{WHERE } f_{n\star} = f_{\mathcal{R}}(\phi_{\star}) = 1 + r_{\mathcal{RK}}(2n\widehat{N}_{\star})^{n/4}.$$

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- A CLEAR EFFICIENT **DEPENDENCE OF THE OBSERVABLES** ON $r_{\mathcal{R}K}$ ARISES, E.G. FOR $n=4$, WE GET

$$n_s = 1 - (f_{m\star}^{1+m} - 1) \frac{m-1 + (m+2)f_{m\star}}{(f_{m\star}-1)f_{m\star}^{1+m}(1+m)\widehat{N}_{\star}}, \quad r = \frac{16(f_{m\star}^{1+m} - 1)}{(f_{m\star}-1)f_{m\star}^{1+m}(1+m)\widehat{N}_{\star}},$$

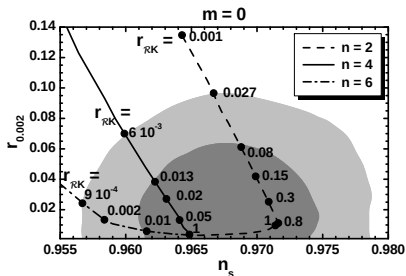
$$\alpha_s = \frac{f_{m\star}^{-2(1+m)}}{(1+m)\widehat{N}_{\star}} \frac{(f_{m\star}^{1+m} - 1)^2}{(f_{m\star} - 1)^2} (2f_{m\star}(1+f_{m\star}) + 3(f_{m\star}-1)f_{m\star}m + (f_{m\star}-1)^2m^2 - 1)$$

- E.G., EXPANDING THE RELEVANT FORMULAS FOR $1/\widehat{N}_{\star} \ll 1$ WE FIND **FOR $n=4$ AND $m=1$** :

$$n_s \simeq 1 - 3/2\widehat{N}_{\star} - 3/8(\widehat{N}_{\star}^3 r_{\mathcal{R}K})^{1/2}, \quad r \simeq 1/2\widehat{N}_{\star}^2 r_{\mathcal{R}K} + 2/(\widehat{N}_{\star}^3 r_{\mathcal{R}K})^{1/2}, \quad \alpha_s \simeq -3/2\widehat{N}_{\star}^2 - 9/16(\widehat{N}_{\star}^3 r_{\mathcal{R}K})^{1/2}$$

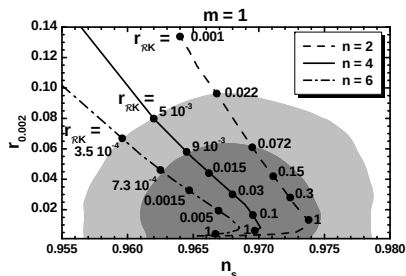
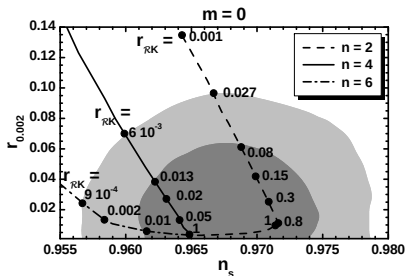
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- IMPOSING THE *Planck* CONSTRAINTS FOR $\hat{N}_* = 55$, $k_S = 0.5 - 1$ AND $k_\Phi = 1$ WE OBTAIN THE FOLLOWING ALLOWED CURVES:



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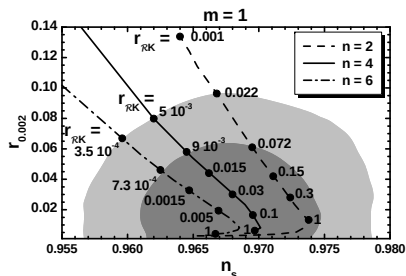
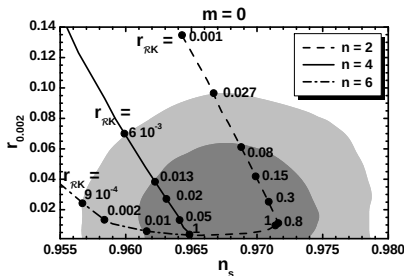
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TESTING AGAINST OBSERVATIONS

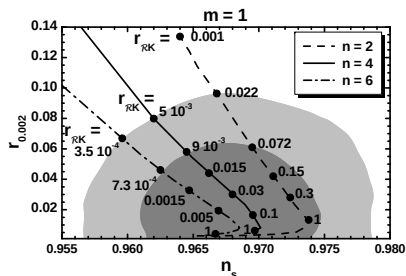
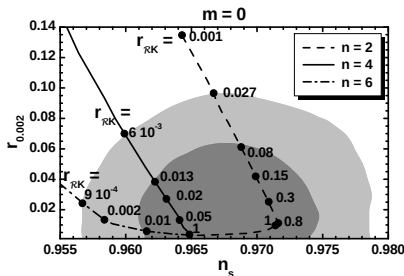
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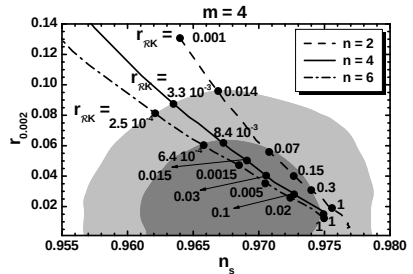
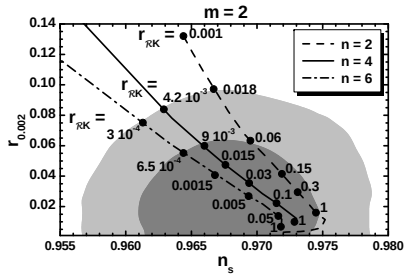
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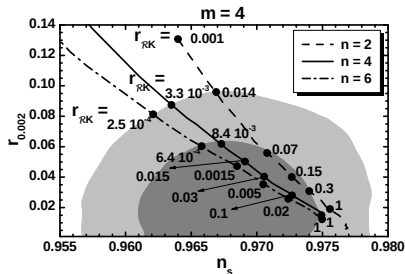
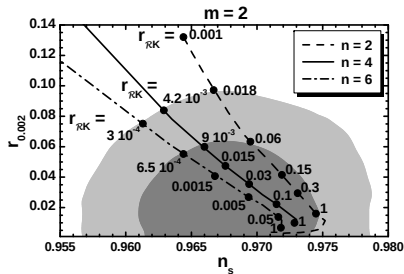


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- APART FROM THE $n = 2$ LINE, THE OTHERS TERMINATE FOR $r_{RK} = 1$, BEYOND WHICH THE MODELS ARE NOT UNITARITY SAFE.
- THE $n = 2$ LINE APPROACHES AN ATTRACTOR VALUE FOR $c_R \gg 1$ AND ANY m .
- FOR $r_{RK} = 1$ WE OBTAIN THE LOWEST r : 0.0032 (FOR $m = 0$ AND $n = 6$) TO 0.015 (FOR $m = 4$ AND $n = 4$).

- For $m = 2$ & $m = 4$ THE CURVES MOVE MORE AND MORE TO THE RIGHT AND TEND TO GO FURTHER FROM THE $1-\sigma$ RANGES:



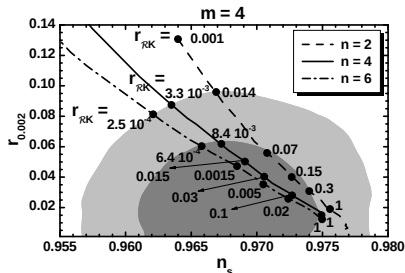
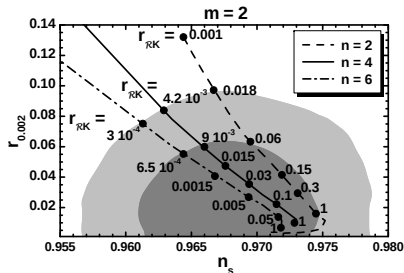
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CONCLUSIONS

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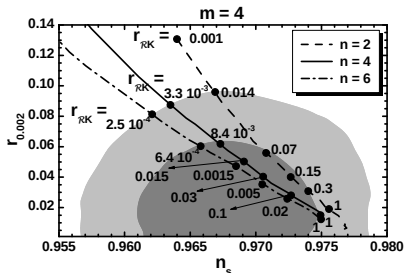
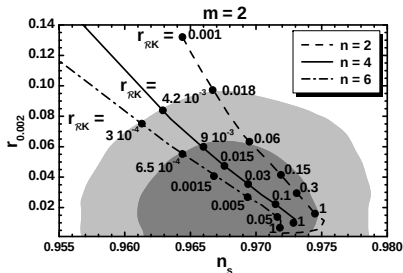
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- This Setting Can Be Elegantly Implemented In Sugra, Employing A **Logarithmic Kähler Potential** Which Includes An Holomorphic Function And A **Shift-Symmetric Quadratic Function** F_K Which Remains Invisible In $\widehat{V}_{CI0}$ While Dominates J .
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- A Sizable Fraction Of The Allowed Parameter Space Of Our Models (With $n = 4$) Can Be Studied **Analytically**.

THANK YOU!

KINETICALLY MODIFIED NON-MINIMAL HIGGS INFLATION WITH $m = 0$

• THE FIELDS INCLUDING THE INFLATON ARE **CHARGED** UNDER A LOCAL SYMMETRY, E.G. $U(1)_{B-L}$. THEN INFLATON CAN BE IDENTIFIED WITH THE RADIAL PART (ϕ) OF THE HIGGS FIELDS INVOLVED IN THE BREAKING $G_{\text{SM}} \times U(1)_{B-L} \rightarrow G_{\text{SM}}$.

• W IS UNIQUELY DETERMINED USING $U(1)_{B-L}$ AND AN R SYMMETRY.

CHARGE ASSIGNMENTS

$$W = \lambda S (\bar{\Phi} \Phi - M^2/4),$$

SUPERFIELDS:	S	Φ	$\bar{\Phi}$
$U(1)_R$	1	0	0
$U(1)_{B-L}$	0	1	-1

• THE SELECTED K 'S ARE INVARIANT UNDER $U(1)_{B-L}$ AND R .

$$K_1 = -N_1 \ln \left(1 - \frac{c_-}{N_1} F_- + c_+ F_+ - \frac{1}{N_1} F_S + \frac{k_-}{N_1} F_-^2 + \frac{k_S}{N_1} F_- |S|^2 \right) \text{ OR } K_2 = -N_2 \ln \left(1 - \frac{c_-}{N_2} F_- + c_+ F_+ \right) + F_S.$$

WHERE $F_{\pm} = |\Phi \pm \bar{\Phi}^*|^2$ AND $F_S = |S|^2 - k_S |S|^4$. NOTE THAT $c_K \rightarrow c_-$ AND $c_R \rightarrow c_+$ AND $f_R = 1 + c_+ \phi$.

• IF WE USE THE PARAMETERIZATION: $\Phi = \phi e^{i\theta} \cos \theta_{\Phi} / \sqrt{2}$ AND $\bar{\Phi} = \phi e^{i\bar{\theta}} \sin \theta_{\Phi} / \sqrt{2}$ ALONG THE D-FLAT DIRECTION $\theta = \bar{\theta} = 0$, $\theta_{\Phi} = \pi/4$ AND $S = 0$, WE OBTAIN

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$$\widehat{V}_{C10} \simeq \frac{\lambda^2 \phi^4}{16 f_R^{2(1+n)}}, \quad \text{WHERE} \quad \begin{cases} N_1 - 1 = 2(1+n) \\ N_2 = 2(1+n) \end{cases} \quad \text{FOR} \quad \begin{cases} K = K_1 \\ K = K_2 \end{cases}$$

• THE EF CANONICALLY NORMALIZED INFLATON IS

$$\frac{d\widehat{\phi}}{d\phi} = J = \sqrt{\frac{c_-}{f_R}} \Rightarrow \widehat{\phi} = \frac{1}{\sqrt{r_{\pm}}} \operatorname{arcsinh} \sqrt{c_+ \phi}$$

AND THE CORRESPONDING EF POTENTIAL IS

$$\widehat{V}_{C10} = \frac{\lambda^2}{4c_+^2} \frac{\tanh^4 \sqrt{r_{\pm}} \widehat{\phi}}{\cosh^{4n} \sqrt{r_{\pm}} \widehat{\phi}} \quad \text{WITH} \quad r_{\pm} = \frac{c_+}{c_-}.$$

