

Title: Inflation: What Now?

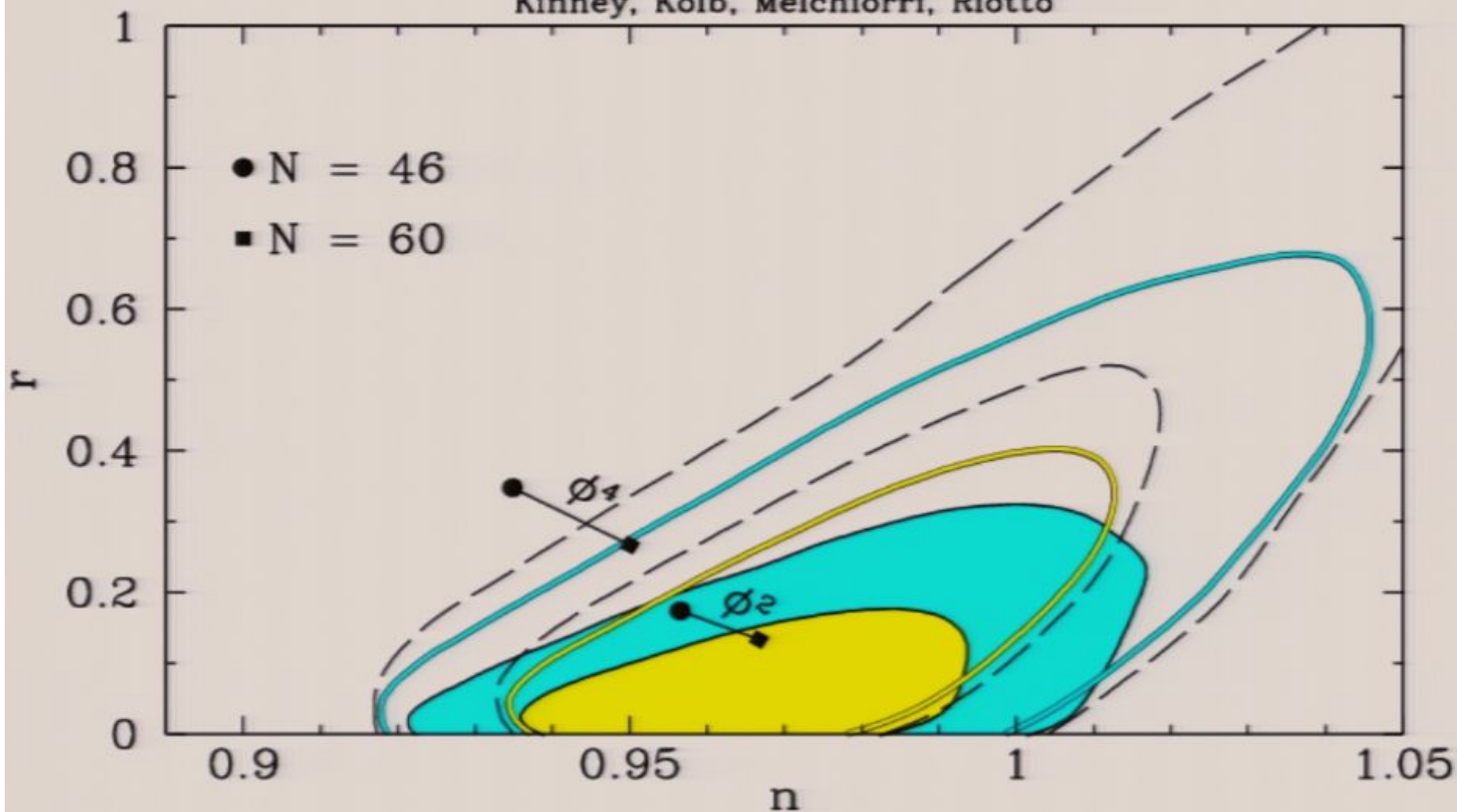
Date: Nov 11, 2006 11:00 AM

URL: <http://pirsa.org/06110047>

Abstract:

WMAP3a (+SDSS) limits on the (n,r) plane

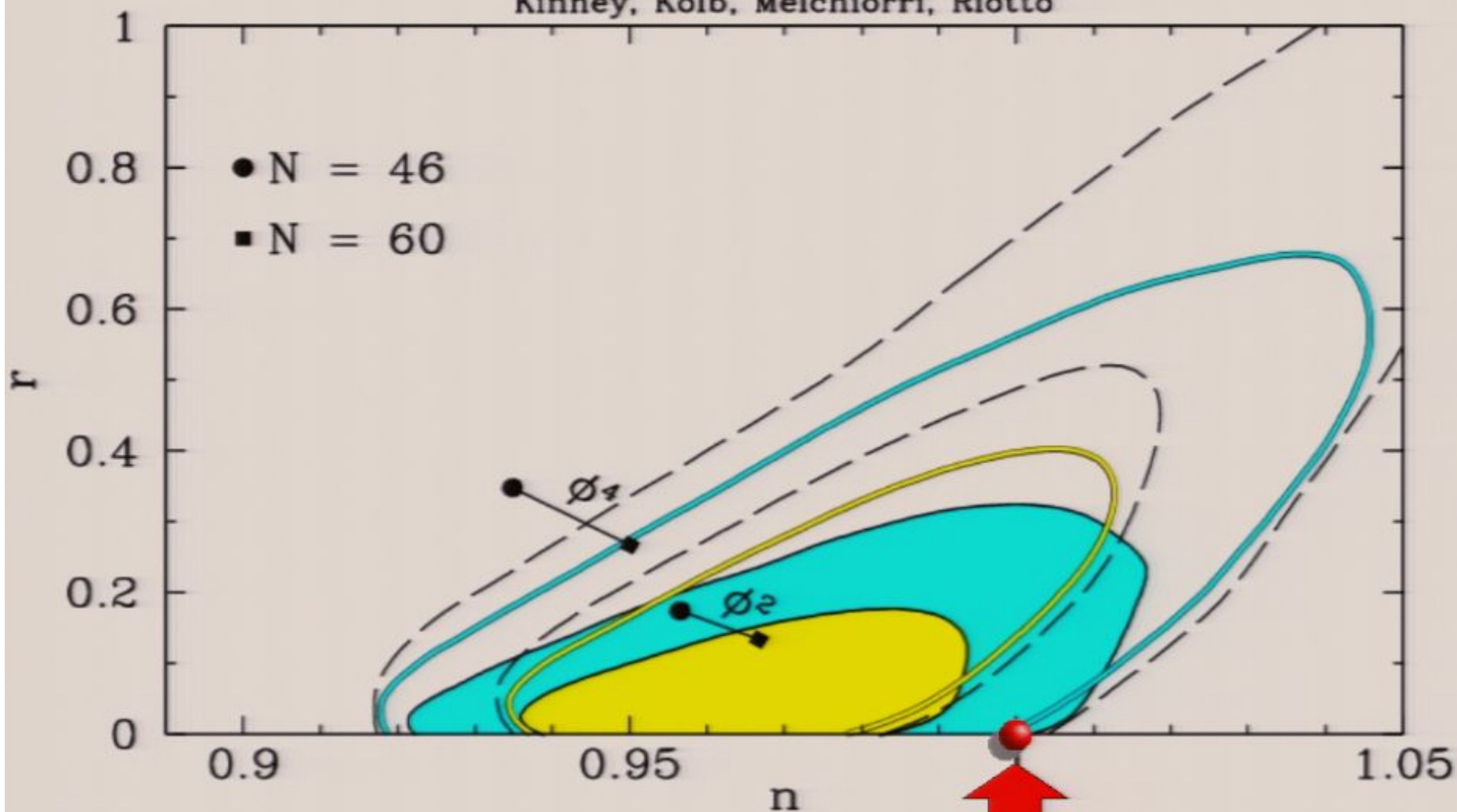
Kinney, Kolb, Melchiorri, Riotto



$r =$ tensor/scalar ratio
 $n =$ scalar spectral index

WMAP3a (+SDSS) limits on the (n,r) plane

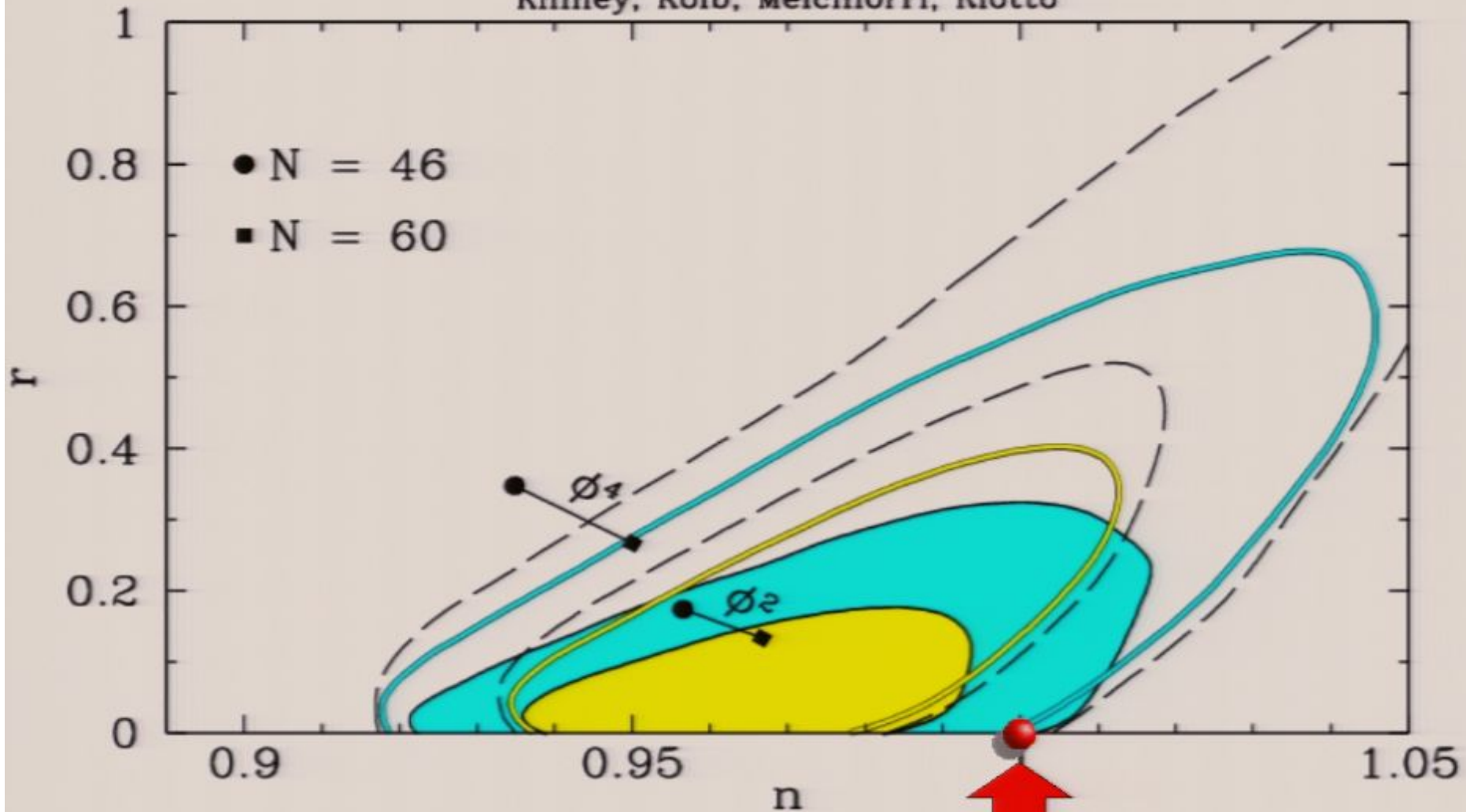
Kinney, Kolb, Melchiorri, Riotto



Scale-invariant limit is consistent with *all data sets!*

WMAP3a (+SDSS) limits on the (n,r) plane

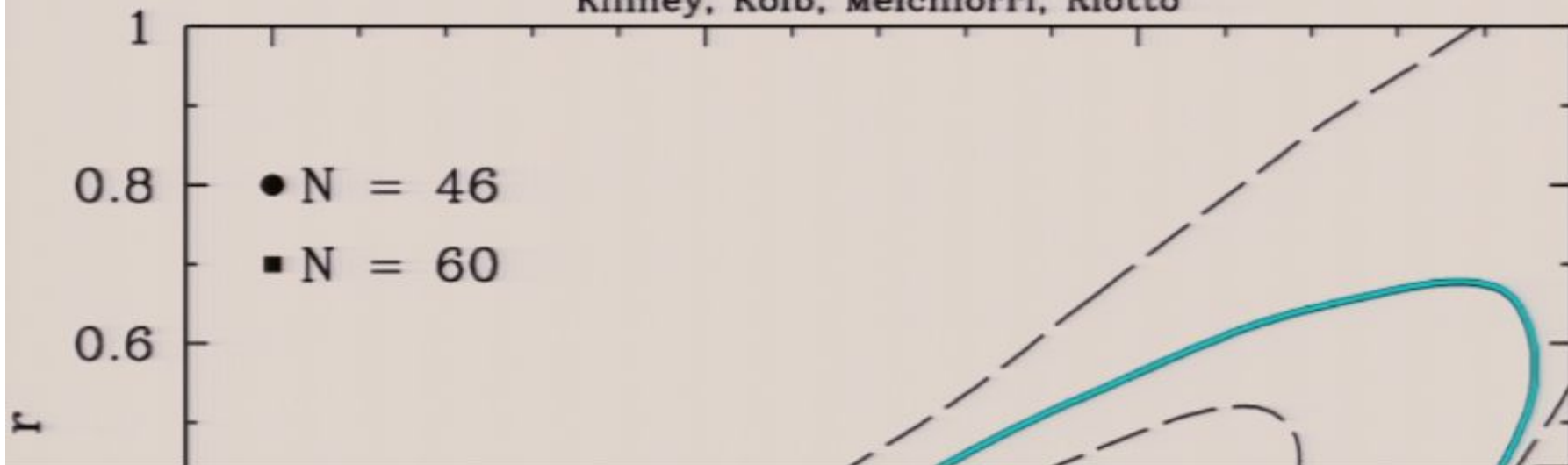
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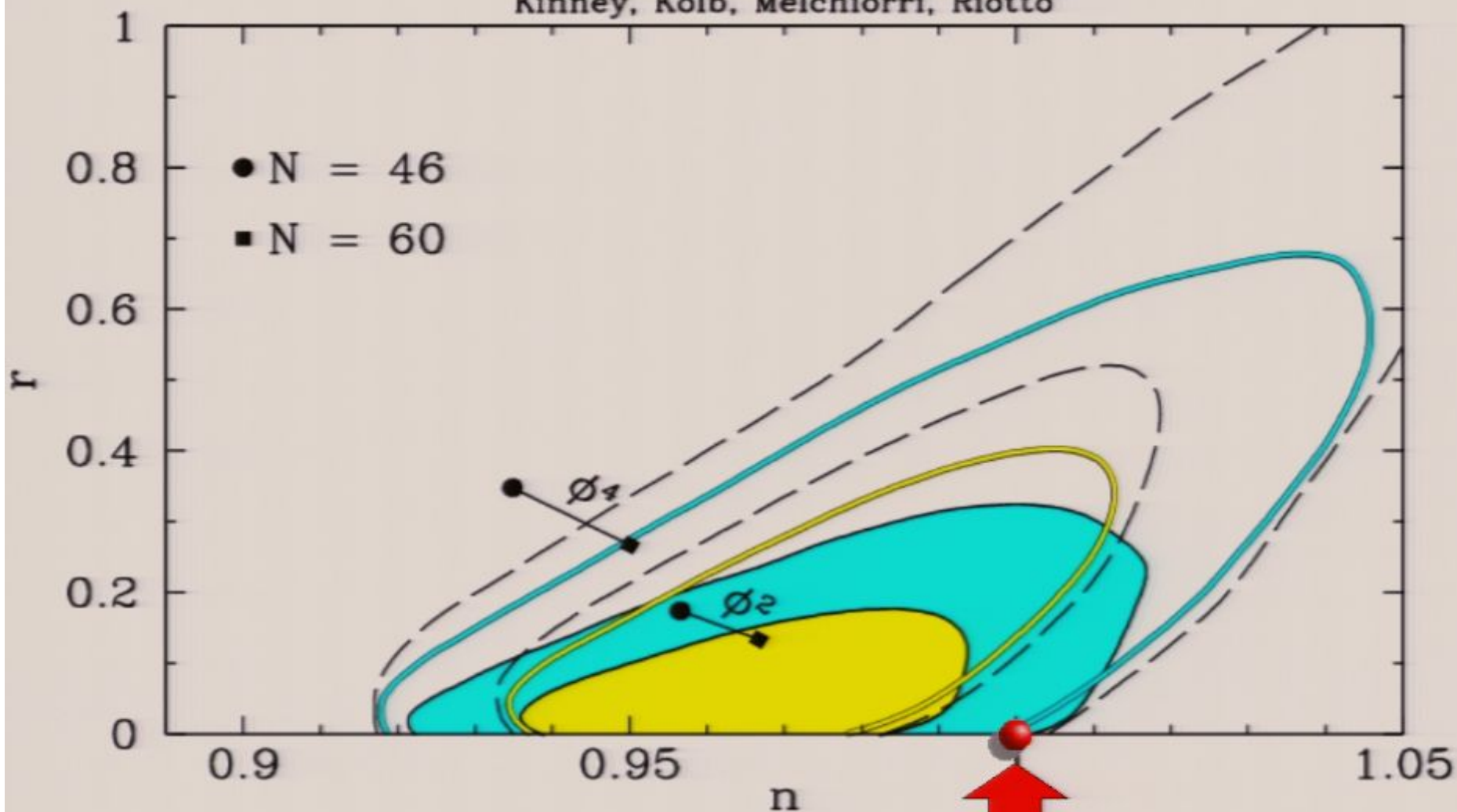
WMAP3a (+SDSS) limits on the (n,r) plane

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Scale-invariant limit is consistent with *all data sets!*

PAPER: 97-94/0503 017

PAPER: gr-qc/0503017

TWO QUESTIONS:

(1) WHAT HAPPENS WHEN $\dot{\phi} \rightarrow 0$?

$$P_R \sim \frac{H^2}{\dot{\phi}}$$

PAPER: gr-94/0503017

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Seto, et al. astro-ph/9911119

Inoue et al. hep-ph/0104083

(2) $\#P_R$

PAPER: gr-qc/0503017

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(2) P_R in non-slow roll models?

MODEL

$$V = V_0 = \text{const.}$$

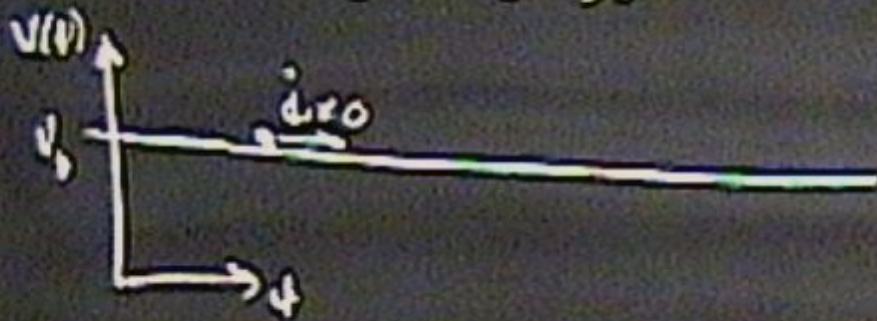
MODEL

$$V = v_0 = \text{const.}$$



MODEL

$$V = V_0 = \text{const.}$$



MODEL

$$\mathcal{L} = \frac{1}{2} m \dot{\phi}^2 + U_0$$

$$V = U_0 = \text{const.}$$



MODEL

$$\mathcal{I} = \frac{1}{2} m^2 \dot{\phi}^2 + V_0$$

$$V = V_0 = \text{const.}$$



EXACTLY SOLVABLE!

$$\ddot{\phi} = -3H\dot{\phi}$$

$$H^2 = \frac{8\pi}{3m^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

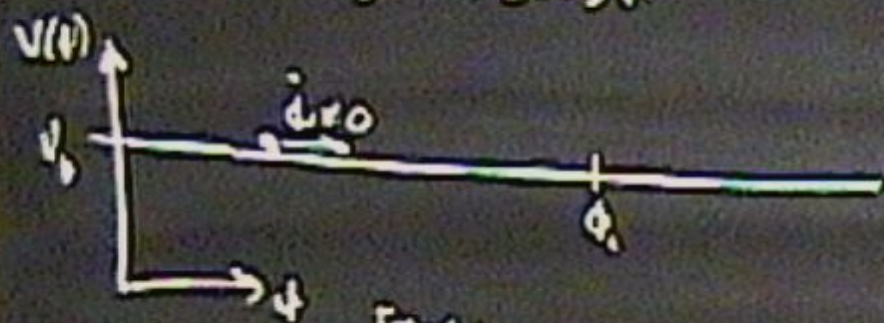
$$H(\phi) = \sqrt{\frac{8\pi V_0}{3m^2}} \cosh \left(\sqrt{\frac{8\pi V_0}{3m^2}} \phi \right)$$

$$\dot{\phi} = \sqrt{2} V_0 \sinh \left(\sqrt{\frac{12\pi}{3m^2}} \phi \right)$$

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PAPER: [REDACTED] 170503017

TWO QUESTIONS:

(1) WHAT HAPPENS WHEN $\dot{\phi} \rightarrow 0$?

$$P_R \sim \frac{H^2}{\dot{\phi}} \rightarrow \infty$$

Seto, et al [hep-ph/9911119](https://arxiv.org/abs/hep-ph/9911119)

Inoue et al [hep-ph/0104083](https://arxiv.org/abs/hep-ph/0104083)

(2) P_R in non-slow roll models?

MODEL

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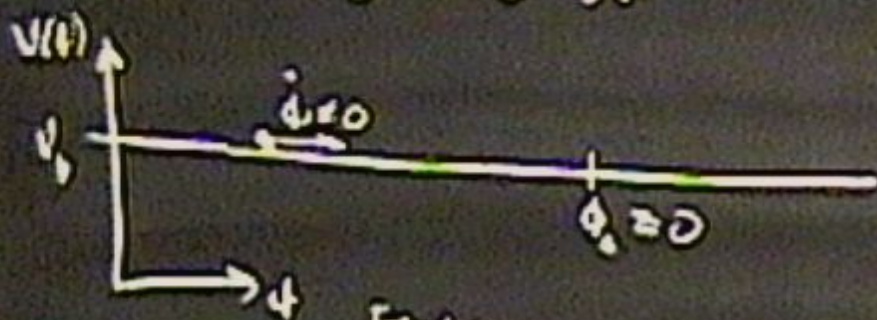
$V = V_0$

(2) Φ_R in non-slow roll models?

MODEL

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$$V = V_0 = \text{const.}$$



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$$H^2 = \frac{8\pi}{3m^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

$$H(\phi) = \sqrt{\frac{8\pi V_0}{3m^2}} \cosh\left(\sqrt{\frac{4\pi}{3m^2}} \phi\right)$$

$$\dot{\phi} = \sqrt{2V_0} \sinh\left(\sqrt{\frac{12\pi}{m^2}} \phi\right)$$

PROBLEM: $H/\dot{\phi} \rightarrow \infty$ $\phi \rightarrow \phi_0$



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BUT WE KNOW $P_R = \langle R_k R_k \rangle = 0$

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$\frac{H}{2\pi}$

PROBLEM: $H/\dot{\phi} \rightarrow \infty$ $\phi \rightarrow \phi_0$

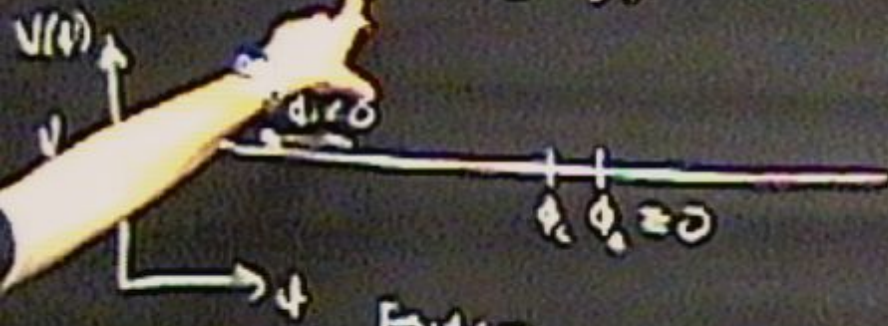
BUT WE KNOW $P_R = \langle R_k R_k \rangle = 0$

$$\delta\phi \sim \frac{H}{2\pi}$$

MODEL

$$\mathcal{L} = \frac{1}{2} m \dot{\phi}^2 + V_0$$

$$V = V_0 = \text{const.}$$



EXACTLY SOLVABLE!

$$\ddot{\phi} = -3H\dot{\phi}$$

$$H^2 = \frac{8\pi}{3M_{\text{pl}}^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

$$H(\phi) = \sqrt{\frac{8\pi V_0}{3M_{\text{pl}}^2}} \cosh \left(\sqrt{\frac{12\pi}{5}} \frac{\phi}{M_{\text{pl}}} \right)$$

$$\dot{\phi} = \sqrt{2V_0} \sinh \left(\sqrt{\frac{12\pi}{5}} \frac{\phi}{M_{\text{pl}}} \right)$$

PROBLEM: $H/\dot{\phi} \rightarrow \infty$ $\phi \rightarrow \phi_0$

BUT WE KNOW $P_R = \langle R_k R_k \rangle = 0$

$$\delta\phi \sim \frac{H}{2\pi}$$

CHOOSE ϕ_c VERY CLOSE TO $\phi_0 = 0$:

WHAT IS P_R NOW?

PROBLEM: $H/\phi \rightarrow \infty$ $\phi \rightarrow \phi_0$

BUT WE KNOW $P_R = \langle R_k R_k \rangle = 0$

$$\delta\phi \sim \frac{H}{2\pi}$$

USE ϕ_c VERY CLOSE TO $\phi_0 = 0$:

WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi^2} \Big|_{k=qH}$$

PROBLEM: $H/\dot{\phi} \rightarrow \infty$ $\phi \rightarrow \phi_0$

BUT WE KNOW $P_R = \langle R_k R_k \rangle = 0$

$$\delta\phi \sim \frac{H}{2\pi}$$

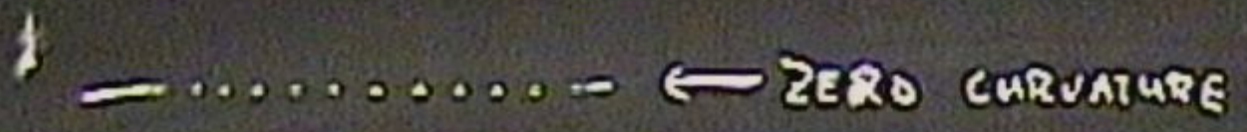
CHOOSE ϕ_c VERY CLOSE TO $\phi_0 = 0$:

WHAT IS P_R NOW?

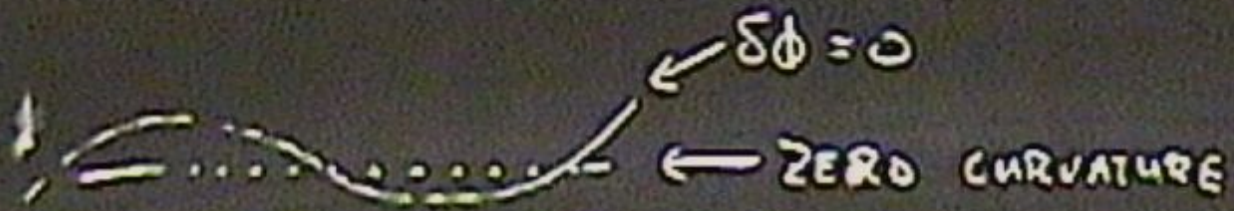
$$P_R = \frac{H^2}{2\pi^2 f} \Big|_{k=qH}$$

... application

δN FORMALISM:

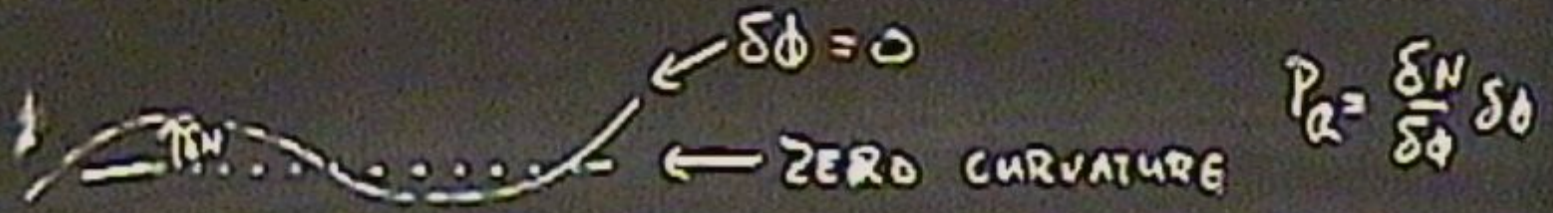


δN FORMALISM:



$\Delta\pi\phi|_{k=0H}$

δN FORMALISM:



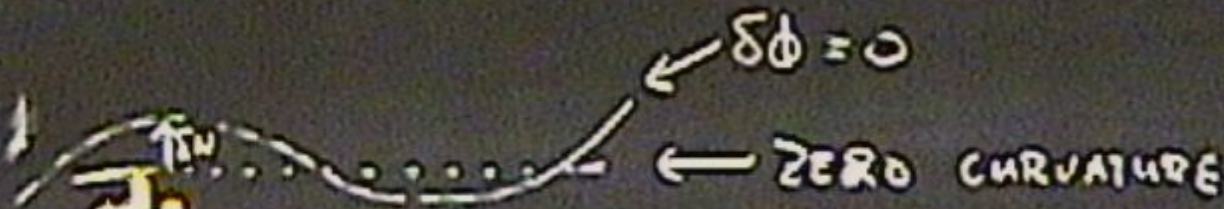
$$\delta\phi \sim \frac{H}{2\pi}$$

CHOOSE ϕ_c VERY CLOSE TO $\phi_0 = 0$:

WHAT IS P_R NOW?

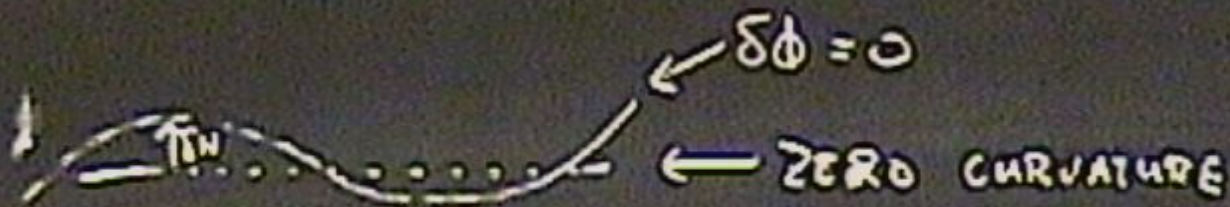
$$P_R = \left. \frac{H^2}{2\pi\dot{\phi}} \right|_{\kappa=4H}$$

δN FORMALISM:



$$P_R = \frac{\delta N}{\delta\phi} \delta\phi$$

δN FORMALISM:

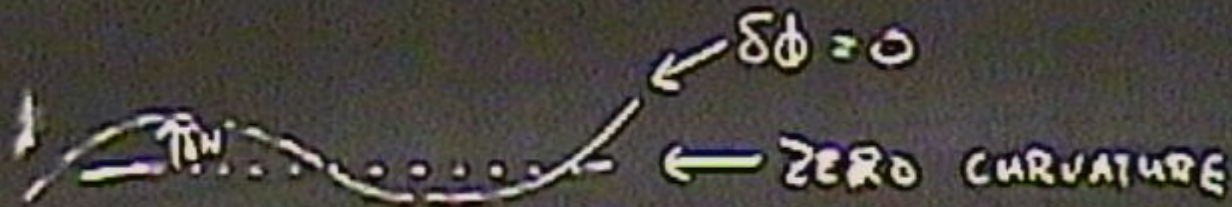


$$P_Q = \frac{\delta N}{\delta \dot{\phi}} \delta \dot{\phi}$$

\hookrightarrow GAGE - INVARIANT VARIABLE

$$u = a \delta \phi - z Q \quad z = \frac{a \dot{\phi}}{H}$$

δN FORMALISM:



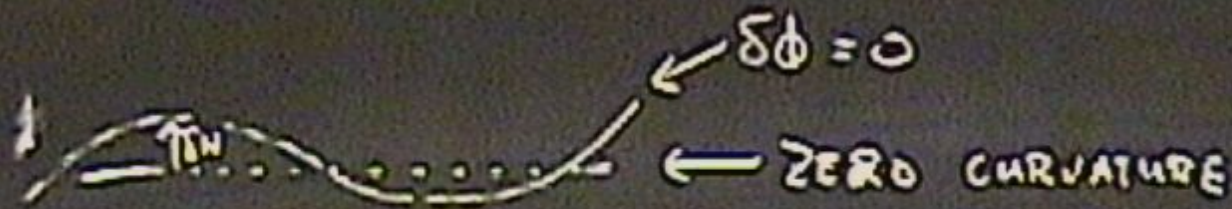
$$P_Q = \frac{\delta N}{\delta \phi} \delta \phi$$

GAUGE-INVARIANT VARIABLE

$$u = a \delta \phi - z Q \quad z = \frac{a \dot{\phi}}{H}$$

CHOOSING GAUGE $\delta \phi = 0$ $u = z Q$ $Q = \frac{u}{z}$

δN FORMALISM:



$$P_Q = \frac{\delta N}{\delta \phi} \delta \phi$$

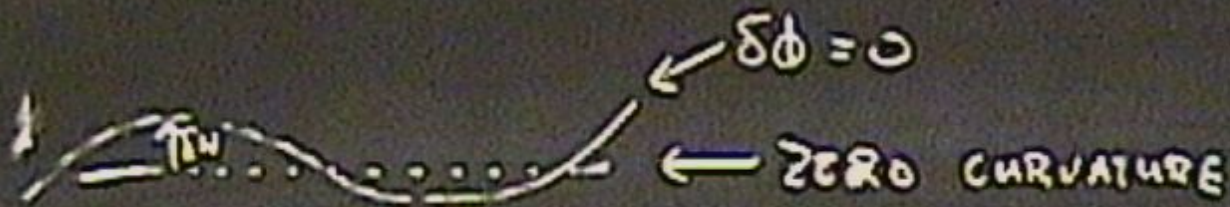
GAUGE-INVARIANT VARIABLE

$$u = a \delta \phi - z Q \quad z = \frac{a \dot{\phi}}{H}$$

WITH GAUGE $\delta \phi = 0$ $u = z Q$ $Q = \frac{u}{z}$

ZERO CURVATURE: $u = a \delta \phi$

δN FORMALISM:



$$P_Q = \frac{\delta N}{\delta \phi} \delta \phi$$

LANGE - INVARIANT VARIABLE

$$U = c \delta \phi - z Q \quad z = \frac{c \dot{\phi}}{N}$$

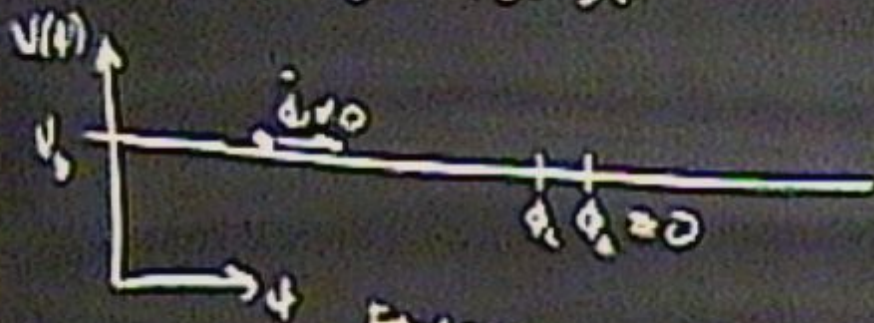
CONVING LANGE $\delta \phi = 0$ $U = z Q$ $Q = \frac{U}{z}$

ZERO CURV. : $U = c \delta \phi$

MODEL

$$\mathcal{L} = \frac{1}{2} m \dot{\phi}^2 + V_0$$

$$V = V_0 = \text{const.}$$



EXACTLY SOLVABLE!

$$\ddot{\phi} = -3H\dot{\phi}$$

$$\frac{1}{2} \dot{\phi}^2 + V_0$$

$$\begin{pmatrix} \sqrt{\frac{E}{3}} \\ \sqrt{\frac{E}{3}} \end{pmatrix} \phi$$

$$\begin{pmatrix} \sqrt{\frac{E}{3}} \\ \sqrt{\frac{E}{3}} \end{pmatrix} \phi$$

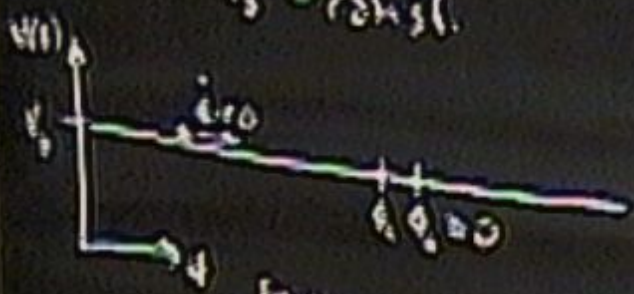
MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

MODEL

$$V = V_0 = \text{const.}$$

$$\mathcal{J} = \frac{1}{2} m \dot{\phi}^2 + V_0$$



EXACTLY SOLVABLE!

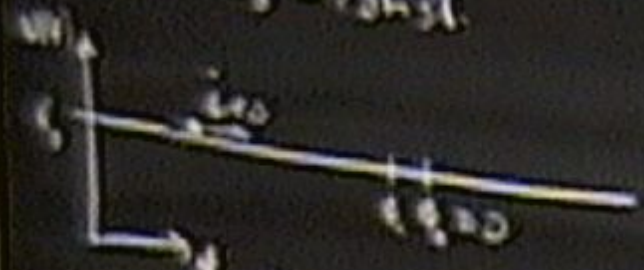
$$\ddot{\phi} = -3H\dot{\phi}$$

$$\left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

$$\begin{pmatrix} \frac{1}{2} \dot{\phi}^2 \\ V_0 \end{pmatrix} e^{-3Ht}$$
$$\begin{pmatrix} \frac{1}{2} \dot{\phi}^2 \\ V_0 \end{pmatrix} e^{-3Ht}$$

MODEL

$V = V_0 = \text{const.}$



EXACTLY SOLVABLE!

$\hat{d} = \frac{1}{2} m^* \dot{\phi}^2 + V_0$

$\ddot{\phi} = -3H\dot{\phi}$

$H^2 = \frac{8\pi}{3m^*} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$

$$H(\phi) = \sqrt{\frac{4m^*V_0}{3m^*}} \cosh\left(\sqrt{\frac{m^*}{4H^2}} \phi\right)$$

$$\dot{\phi} = \sqrt{2V_0} \sinh\left(\sqrt{\frac{12\pi}{m^*}} \phi\right)$$

MODIFIED EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$\epsilon(\phi) = 3 \tanh^2 \left(\sqrt{\frac{12\pi}{m_{\text{pl}}^2}} \phi \right),$$

$$\eta(\phi) \approx \frac{11''}{H} = 3$$

MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$\epsilon(\phi) = 3 \sqrt{\frac{12\pi}{m_{pl}^2}} \phi$$

$$\eta(\phi) \approx \frac{H^2}{H^{\prime 2}} = 3$$

$$\zeta^2(u) = 3 \epsilon^2(\phi)$$

MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$u_k'' + (k^2 - 2a^2 H^2) u_k = 0$$

$$\epsilon(\phi) = 3 \epsilon_{\text{eff}} h^2 \left(\sqrt{\frac{12\pi}{m_{\text{pl}}^2}} \phi \right)$$

$$\eta(\phi) \approx \frac{H''}{H} = 3$$

$$\zeta^2(u) = 3 \epsilon_{\text{eff}}(\phi)$$

MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$u_k'' + (k^2 - 2a^2 H^2) u_k = 0$$

$$u_k = A_k H_{3/2}(-k\epsilon) + B_k H_{-3/2}(-k\epsilon)$$

$$\epsilon(\phi) = 3 \epsilon_{\text{pl}} h^2 \left(\sqrt{\frac{12\pi}{m_{\text{pl}}^2}} \phi \right)$$

$$\eta(\phi) \approx \frac{H''}{H} = 3$$

$$\zeta^2(u) = 3 \epsilon(\phi)$$

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$$\text{B. D.} \Rightarrow u_k = N_k H_{3/2}(-kz)$$

$$\epsilon(\phi) = 3 \epsilon_0 \hbar^2 \left(\sqrt{\frac{12\pi}{m_p^2}} \phi \right)$$

$$\eta(\phi) \propto \frac{H''}{H} = 3$$

$$\zeta^2(u) = 3 \epsilon_0(\phi)$$

MODI EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$u_k'' + (k^2 - 2a^2 H^2) u_k = 0$$

$$u_k = A_k H_{3/2}(-k\tau) + B_k H_{-3/2}(-k\tau)$$

$$\text{B. D.} \Rightarrow u_k = N_k H_{3/2}(-k\tau)$$

$$\epsilon(\phi) = 3 \epsilon_{\text{pl}} h^2 \left(\sqrt{\frac{13\pi}{m_{\text{pl}}^2}} \phi \right)$$

$$\eta(\phi) \approx \frac{H''}{H} = 3$$

$$\zeta^2(\phi) = 3 \epsilon(\phi)$$

$$P_R = \sqrt{\frac{k^5}{2\pi f}} \left| \frac{u_k}{z} \right| = \left(\frac{H^2}{2\pi\phi} \right)$$

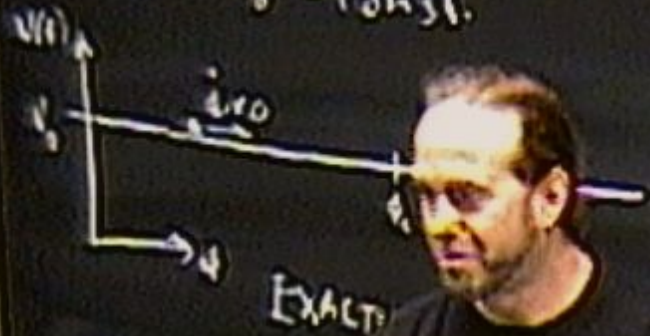
$$B. D. \Rightarrow u_k = N_k H_{3/2}(-k\epsilon)$$

$$P_R = \left| \frac{k^5}{2\pi i} \right| \left| \frac{u_k}{z} \right| = \left(\frac{1}{2\pi b} \right)$$

$$P_R = \left(\frac{1}{2\pi b} \right)_{k=0}^{\infty} \Rightarrow n = 1 + 2\eta = 7$$

MODEL

$V = V_0 = \text{const.}$



$\mathcal{L} = \frac{1}{2} m^2 \dot{\phi}^2 + V_0$

$\ddot{\phi} = -3H\dot{\phi}$

$H^2 = \frac{8\pi}{3m^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$

$H(\phi) = \sqrt{\frac{4\pi V_0}{3m^2}} \cosh\left(\sqrt{\frac{4\pi}{3}} \phi\right)$

$\dot{\phi} = \sqrt{2V_0} \sinh\left(\sqrt{\frac{12\pi}{3}} \phi\right)$

δN F



Gauge -

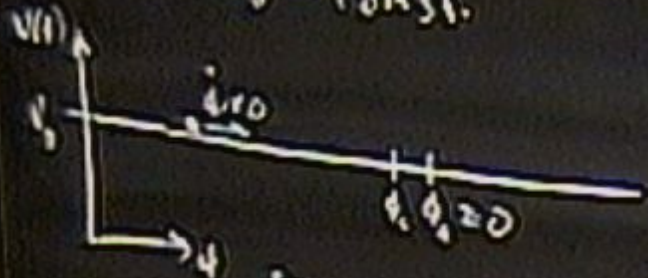
$U = a$

CONVING

BERO CURV.

MODEL

$V = V_0 = \text{const.}$



EXACTLY SOLVABLE!

$\mathcal{L} = \frac{1}{2} m^2 \dot{\phi}^2 + V_0$

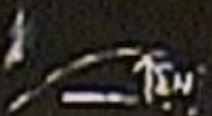
$\ddot{\phi} = -3H\dot{\phi}$

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$$H(\phi) = \sqrt{\frac{4V_0}{3m^2}} \cosh\left(\sqrt{\frac{4V_0}{3}} \phi\right)$$

$$\dot{\phi} = \sqrt{2V_0} \sinh\left(\sqrt{\frac{12V_0}{3}} \phi\right)$$

δN F



Gauge -

$U = \alpha$

CONVING

RES

$$B. D. \Rightarrow u_k = N_k H_{3/2}(-k\epsilon)$$

$$P_R = \left| \frac{k^5}{2\pi i} \right| \left| \frac{u_k}{z} \right| = \left(\frac{H}{2\pi\phi} \right)$$

$$P_R = \left(\frac{H^2}{2\pi i b} \right)_{k=0} \Rightarrow n = 1 + 2\eta = 0$$

$$\frac{u_k''}{u_k} = \frac{z''}{z}$$

$$P_R = \left(\frac{H^2}{\lambda \pi i} \right)_{\substack{\text{all } \rightarrow 0 \\ \text{all } \rightarrow 0}} \Rightarrow n = 1 + 2\eta = 0$$

$$\frac{u_k''}{u_k} = \frac{z''}{z}$$

$$P_Q = \left(\frac{H^2}{\lambda \pi i} \right)_{\Phi=0} \quad n-1=0$$

$$P_R = \left(\frac{1}{2\pi i} \right)_{\phi=0}^{\phi=2\pi} \Rightarrow n = 1 + 2\gamma = 7$$

$$\frac{U_k''}{U_k} = \frac{z''}{z}$$

$$P_Q = \left(\frac{H^2}{2\pi i} \right)_{\phi=0}^{\phi=2\pi} \quad n-1=0$$

SLOW ROLL

$$y \equiv \frac{k}{aH}$$

$$P_R = \left(\frac{H^2}{24i} \right)_{\text{slow roll}} \Rightarrow n = 1 + 2\eta = 2$$

$$\frac{U_{kk}}{U_k} = \frac{2''}{2'}$$

SLOW ROLL

$$P_R = \left(\frac{H^2}{24i} \right)_{\text{slow roll}}$$

$$n-1=0$$

$$n=3(1-\nu)$$

$$\eta \equiv \frac{k}{aH}$$

$$\delta N_k = \frac{U^2}{4} \eta^{3/2-\nu}$$

$$\nu: \mathcal{H}_\nu()$$

$$P_R = \left(\frac{H^2}{2\pi i} \right)_{\phi=0} \Rightarrow n = 1 + 2\gamma = 7$$

$$\frac{U_k''}{U} = \frac{z''}{z}$$

CASE ROLL

$$\gamma \equiv \frac{k}{aH}$$

$$P_R = \left(\frac{H^2}{2\pi i} \right)_{\phi=0}$$

$$n - 1 = 0$$

$$n = 3(1 - \nu)$$

$$\nu: \nu(\cdot)$$

$$\delta N_k \equiv \frac{H^2}{\phi} \gamma^{3/2 - \nu}$$

depends on k/aH

$$u_{1k} = A_k H_{3/2}(-kz) + B_k H_{-3/2}(-kz)$$

$$\text{B. D.} \Rightarrow u_{1k} = N_k H_{3/2}(-kz)$$

$$P_R = \sqrt{\frac{k^5}{2\pi H}} \left| \frac{u_k}{z} \right| = \left(\frac{H^2}{2\pi \phi} \right)$$

$$P_R = \left(\frac{H^2}{2\pi \phi} \right)_{\phi = \phi_c}$$

$$n-1=0$$

$$n=3(1-\nu)$$

$$\nu: \nu(\cdot)$$

$$\delta N_k \equiv \frac{H^2}{\phi} y^{3/2-\nu}$$

depends on k/aH

$$r_R = \left(\frac{2\pi i b}{aH} \right)_{\phi = \phi_0} \Rightarrow n = 1 + 2\gamma = 7$$

$$\frac{U_{kk}''}{U_{kk}} = \frac{z''}{z}$$

$$P_R = \left(\frac{H^2}{2\pi i} \right)_{\phi = \phi_0}$$

$$n - 1 = 0$$

$$n = 3(1 - \nu)$$

SLOW ROLL

$$y \equiv \frac{k}{aH}$$

$$\delta N_k \equiv \frac{H^2}{\phi} y^{3/2 - \nu}$$

depends on k/aH

$$\nu : \nu(\phi)$$

SLOW ROLL

$$y \equiv \frac{k}{aH}$$

$$\delta N_{\mathcal{R}} \equiv \frac{H^2}{4\pi} y^{3/2-\nu}$$

depends on k/aH

$$n = 3(1-\nu)$$

$$\nu: H_{\nu}(\cdot)$$

$$u_{\mathcal{R}} = H_{\nu}(y) \rightarrow \frac{H^2}{4\pi} y^{3/2-\nu} \quad y \rightarrow 0$$

$$y \equiv \frac{k}{aH}$$

$$\delta N_s = \frac{H^2}{4\pi} y^{3/2 - \nu}$$

depends on k/aH

$$\nu: H_\nu(\cdot)$$

$$u_{\nu c} = H_\nu(y) \rightarrow \frac{H^2}{4\pi} y^{3/2 - \nu}$$

δN_s

$$y \equiv \frac{k}{aH}$$

$$\delta N_s \equiv \frac{H^2}{\phi} y^{3/2 - \nu}$$

depends on k/aH

$$\nu: H_\nu(\cdot)$$

$$u_k = H_\nu(y) \rightarrow \frac{H^2}{\phi} y^{3/2 - \nu} \quad y \rightarrow 0$$

$$\delta N_s(y=1) = \frac{H^2}{\phi} \Big|_{k=aH}$$

$$y \equiv \frac{k}{aH}$$

$$\delta N_s = \frac{H^2}{\phi} y^{3/2 - \nu}$$

depends on k/aH

$$\nu: H_\nu(\cdot)$$

$$u_k = H_\nu(y) \rightarrow \frac{H^2}{\phi} y^{3/2 - \nu} \quad y \rightarrow 0$$

$$\delta N_s(y=1) = \frac{H^2}{\phi} \Big|_{k=aH}$$

$$y \equiv \frac{k}{aH}$$

$$\delta N_x = \frac{H^2}{\phi} y^{3/2 - \nu}$$

depends on k/aH

$$\nu: H_\nu(\cdot)$$

$$u_k = H_\nu(y) \rightarrow \frac{H^2}{\phi} y^{3/2 - \nu} \quad y \rightarrow 0$$

$$\frac{d\delta N_x}{dk} \sim O(\epsilon^2)$$

$$\delta N_i(y=1) = \frac{H^2}{\phi} \Big|_{k=aH}$$

$$y \equiv \frac{k}{aH}$$

$$\delta N_s = \frac{H^2}{\phi'} y^{3/2 - \nu}$$

depends on k/aH

$$\nu : H_\nu(\cdot)$$

$$u_k = H_\nu(y) \rightarrow \frac{H^2}{\phi'} y^{3/2 - \nu}$$

$$\frac{d\delta N_s}{dk} \sim O(\epsilon^2)$$

$$\delta N_s(y=1) = \frac{H^2}{\phi'} \Big|_{k=aH}$$

$$\frac{d\delta N_s}{dk} \sim -3$$

MODEL EQUATION

$$u_k'' + \left(k^2 - \frac{z''}{z} \right) u_k = 0$$

$$u_k'' + (k^2 - 2a^2 H^2) u_k = 0$$

$$u_k = A_k H_{3/2}(-k\tau) + B_k H_{-3/2}(-k\tau)$$

$$\Rightarrow u_k = N_k H_{3/2}(-k\tau)$$

$$\epsilon(\phi) = 3\epsilon_p / h^2 \left(\left| \frac{12\pi}{m_{pl}^2} \phi \right| \right)$$

$$\eta(\phi) \approx \frac{H''}{H} = 3$$

$$\zeta^2(k) = \frac{2}{k^2} \epsilon(\phi)$$

$$P_R = \sqrt{\frac{k^3}{2\pi f}} \left| \frac{u_k}{z} \right| = \left(\frac{H^2}{2\pi\phi} \right)$$

$$i(\phi=1) = \frac{H}{\dot{\phi}} \Big|_{k=0} \approx 11$$

$$\frac{u_k}{z} \approx -3$$

CHOOSE ψ_c VERY CLOSE TO $\psi_0 = 0$:

WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi\hbar} \Big|_{k=0}^k$$

~~THE FORMALISM:~~

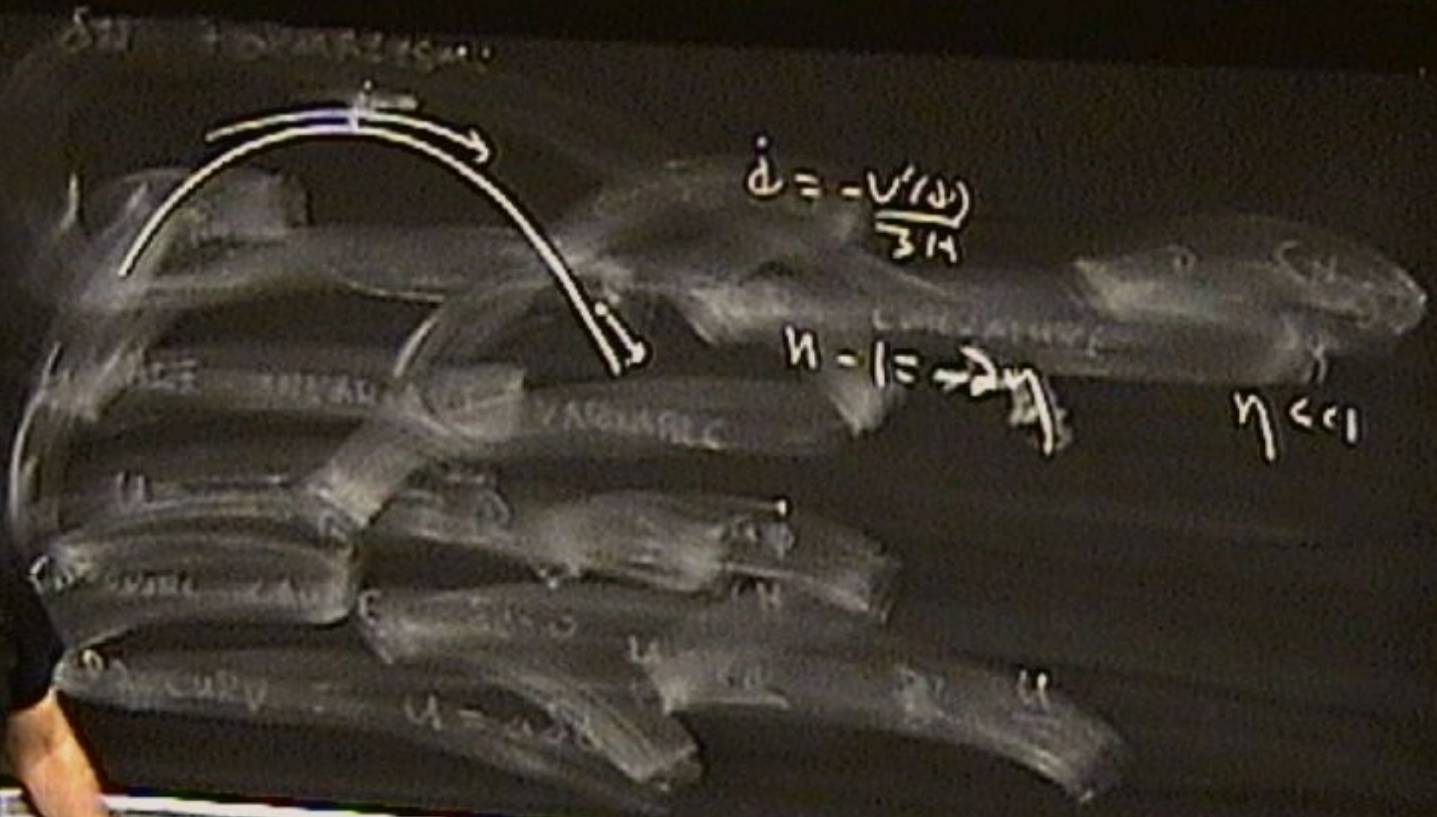


$$\dot{\psi} = -\frac{V(\psi)}{3H}$$

CHOOSE ω_c VERY CLOSE TO $\omega_0 = 0$:

WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi f} \Big|_{\omega=\omega_c}$$



CHOOSE ψ_0 VERY CLOSE TO $\psi_0 = 0$:
 WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi f} \Big|_{k=4H}$$

SUPERSLOW ROLL



$$\dot{\psi} = -\frac{V(\psi)}{3H}$$

SLOW ROLL

$$n = 1 \Rightarrow 2\eta_0$$

$$\eta_0 \ll 1$$

FAST ROLL

$$\eta = 3 - \eta_0$$

VERY CLOSE TO $d_0 = 0$:
 WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi f} \Big|_{k=ak}$$



$$\dot{\phi} = -\frac{v'(v)}{3H}$$

SLOW ROLL

$$n-1 \rightarrow 2\eta_0$$

$$\eta_0 \ll 1$$

FAST ROLL

$$n-1 = 2\eta$$

$$\eta = 3 - \eta_0$$

$$n-1 = 3 - 2\eta - 3$$

VERY CLOSE TO $\psi_c = 0$:
 WHAT IS P_R NOW?

$$P_R = \frac{H^2}{2\pi f} \Big|_{k=aH}$$

SU(2) FORMALISM



$$\psi(u) = \psi_+ e^{r_+ u} + \psi_- e^{r_- u}$$

$$\eta = \eta_0$$

$$= 3 - \eta_0$$

$$\dot{\psi} = -\frac{V'(\psi)}{3H}$$

SLOW ROLL

$$n-1 = 2\eta_0$$

$$\eta_0 < 1$$

FAST ROLL

$$n-1 = 2\eta$$

$$\eta = 3 - \eta_0$$

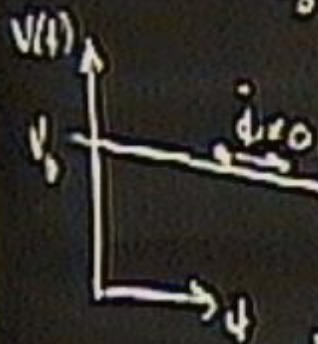
$$n-1 = 3 - 2\eta - 3$$

... von Modellen!

MODEL

$$\mathcal{L} = \frac{1}{2} m \dot{\phi}^2 + V_0$$

$$V = V_0 = \text{const.}$$



EXACTLY SOLVABLE

$$\ddot{\phi} = -3H\dot{\phi}$$

$$H^2 = \frac{8\pi}{3m_{pl}^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

$$\left[\frac{8\pi V_0}{3m_{pl}^2} \cosh \left(\sqrt{\frac{12}{5}} \frac{H}{\sqrt{3}} \phi \right) \right]$$

$$V_0 \sinh \left(\sqrt{\frac{12}{5}} \frac{H}{\sqrt{3}} \phi \right)$$

MODEL

$$V = V_0 = \text{const.}$$



$$\mathcal{L} = \frac{1}{2} m^2 \dot{\phi}^2 + V_0$$

$$\frac{1}{2} \dot{\phi}^2 \ll V(\phi)$$

$$\ddot{\phi} = -3H\dot{\phi}$$

$$H^2 = \frac{8\pi}{3m^2} \left(\frac{1}{2} \dot{\phi}^2 + V_0 \right)$$

$$H(\phi) = \sqrt{\frac{8\pi V_0}{3m^2}} \cosh\left(\sqrt{\frac{4\pi}{3}} \phi\right)$$

$$\dot{\phi} = \sqrt{2V_0} \sinh\left(\sqrt{\frac{4\pi}{3}} \phi\right)$$

$$\psi(u) = \phi$$

$$r_+ = \eta_0$$

$$r_- = 3$$