

Origin of structure

David H. Lyth

Particle Theory and Cosmology Group

Physics Department

Lancaster University

Who is ϕ ?

MASTER FORMULA

$$\zeta = \frac{dN}{d\phi} \delta\phi + \frac{1}{2} \frac{d^2 N}{d\phi^2} (\delta\phi)^2 + \dots$$

$\delta\phi$ generated at horizon exit (from vac fluc except warm inflation)

Who is ϕ ?

MASTER FORMULA

$$\zeta = \frac{dN}{d\phi} \delta\phi + \frac{1}{2} \frac{d^2 N}{d\phi^2} (\delta\phi)^2 + \dots$$

$\delta\phi$ generated at horizon exit (from vac fluc except warm inflation)

Who is ϕ ?

Who is ϕ ?

MASTER FORMULA

$$\zeta = \frac{dN}{d\phi} \delta\phi + \frac{1}{2} \frac{d^2 N}{d\phi^2} (\delta\phi)^2 + \dots$$

$\delta\phi$ generated at horizon exit (from vac fluc except warm inflation)

Who is ϕ ?

1. STANDARD SCENARIO: inflaton in a slow roll model
2. VARIANTS: inflaton in k -inflation/ghost inflation

In both cases $N' = H/\dot{\phi}$ AT HORIZON EXIT determines ζ

Who is ϕ ?

MASTER FORMULA

$$\zeta = \frac{dN}{d\phi} \delta\phi + \frac{1}{2} \frac{d^2N}{d\phi^2} (\delta\phi)^2 + \dots$$

$\delta\phi$ generated at horizon exit (from vac fluc except warm inflation)

Who is ϕ ?

1. STANDARD SCENARIO: inflaton in a slow roll model
2. VARIANTS: inflaton in k -inflation/ghost inflation

In both cases $N' = H/\dot{\phi}$ AT HORIZON EXIT determines ζ

3. TWO-COMPONENT S.R.I.: inflaton has two components
4. END-OF-INFLATION: field affecting end of hybrid inflation

inflation model determines ζ

Curvaton-type scenarios

more ϕ candidates

ϕ affects an event after inflation

eg. preheating, reheating, a second reheating

Curvaton-type scenarios

more ϕ candidates

ϕ affects an event after inflation

eg. preheating, reheating, a second reheating

Inflation model IRRELEVANT for curvaton-type scenarios

(except for $\epsilon(t) \equiv \dot{H}/H^2$)

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

TENSOR FRACTION (before 2010)

$r > 10^{-2}$ small-field s.r.i. ruled out

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

Tensor Fraction (before 2010)

$r > 10^{-2}$ small-field s.r.i. ruled out

$r < 10^{-2}$ curvaton-type ruled out (if inflation is slow roll)

$r < 10^{-2}$ large-field s.r.i. ruled out

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

Tensor Fraction (before 2010)

$r > 10^{-2}$ small-field s.r.i. ruled out

$r < 10^{-2}$ curvaton-type ruled out (if inflation is slow roll)

$r < 10^{-2}$ large-field s.r.i. ruled out

Spectral Index Running (before 2010?)

$n' \gtrsim 10^{-2}$ s.r.i. ruled out for most potentials

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

Tensor Fraction (before 2010)

$r > 10^{-2}$ small-field s.r.i. ruled out

$r < 10^{-2}$ curvaton-type ruled out (if inflation is slow roll)

$r < 10^{-2}$ large-field s.r.i. ruled out

Spectral Index Running (before 2010?)

$n' \gtrsim 10^{-2}$ s.r.i. ruled out for most potentials

Non-Gaussianity (ongoing, but $|f_{\text{NL}}| < 1$ impossible?)

$|f_{\text{NL}}| > 10^{-2}$ s.r.i. ruled out

Ruling out ϕ candidates

Observation of n and r is ruling out s.r.i. for specific potentials

Tensor Fraction (before 2010)

$r > 10^{-2}$ small-field s.r.i. ruled out

$r < 10^{-2}$ curvaton-type ruled out (if inflation is slow roll)

$r < 10^{-2}$ large-field s.r.i. ruled out

Spectral Index Running (before 2010?)

$n' \gtrsim 10^{-2}$ s.r.i. ruled out for most potentials

Non-Gaussianity (ongoing, but $|f_{\text{NL}}| < 1$ impossible?)

$|f_{\text{NL}}| > 10^{-2}$ s.r.i. ruled out

$|f_{\text{NL}}| < 1$ curvaton-type and k-inf/ghost strongly disfavoured

Discovering ϕ candidates

Observation of n and $r \simeq 0.1$ could **confirm** a large-field s.r.i. $V(\phi)$

eg. chaotic inflation or Natural inflation

Discovering ϕ candidates

Observation of n and $r \simeq 0.1$ could **confirm** a large-field s.r.i. $V(\phi)$

eg. chaotic inflation or Natural inflation

Observation of n and $n' \simeq 10^{-3}$ could **confirm** a small-field s.r.i. $V(\phi)$

eg. the original New Inflation potential

Discovering ϕ candidates

Observation of n and $r \simeq 0.1$ could **confirm** a large-field s.r.i. $V(\phi)$

eg. chaotic inflation or Natural inflation

Observation of n and $n' \simeq 10^{-3}$ could **confirm** a small-field s.r.i. $V(\phi)$

eg. the original New Inflation potential

Observation of **predicted** $f_{\text{NL}}(k_1, k_2, k_3) \sim 10^{-2}$ would **confirm** s.r.i.

(a complicated function, found by Maldacena)

Suggestions for next year's research

K-INF/GHOST INF

Cheung et. al. 0709.0293 hep-ph gives a generic lagrangian.

Work out lower bound on f_{NL} within some stated restriction on the parameter space.

Suggestions for next year's research

K-INF/GHOST INF

Cheung et. al. 0709.0293 hep-ph gives a generic lagrangian.

Work out lower bound on f_{NL} within some stated restriction on the parameter space.

NON-SUPERSYMMETRIC S.R.I. MODELS (PNGB)

Cohn/Stewart HEP-PH 0001333; N. Arkani-Hamed et. al.

hep-th/0302034; Kaplan/Weiner hep-ph/0302014

Old and forgotten models:

Work out n and n' as function of parameters.

Are these models already disfavoured by data?

Summary

Origin of structure: a **rich** and **complicated** research area

LHC will **suggest** future directions
—but we can ignore those suggestions

Astro observations (PLANCK etc) will **rule out** some existing proposals, perhaps most of them.

Conceivably, could **confirm** a proposal.