Lyth

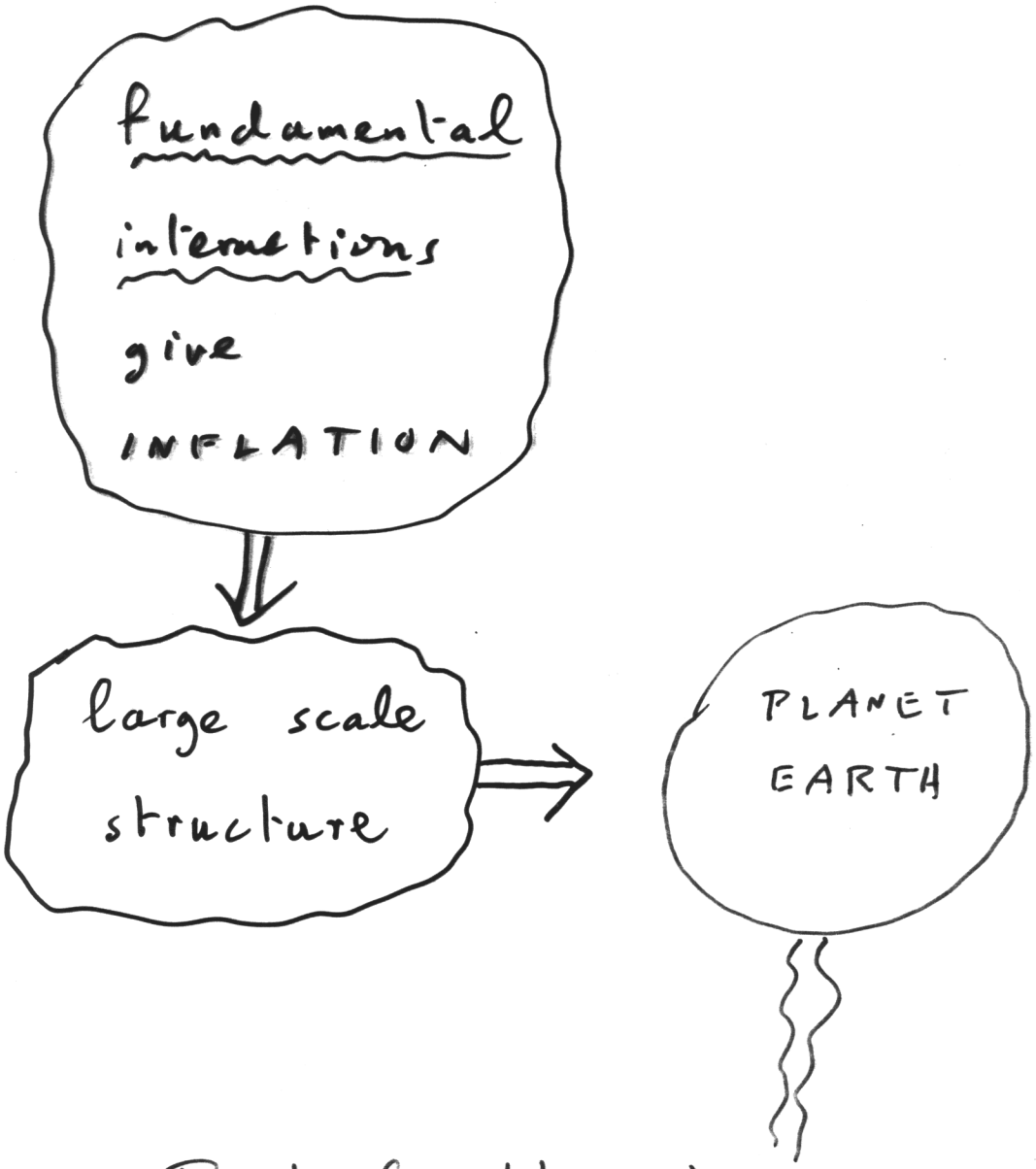
F-term inflation in weakly coupled string theory

CLLSW Copeland, Liddle, Lyth, Stewart, Wands 1994

S Stewart 1995

Gaillard, Lyth & Murayama hep-th/9806157

1. Models of inflation
2. Ways of keeping potential flat-
   D-term inflation 
3. Weakly coupled string theory potential
4. A D term drives F-term inflation



Particle theorists use astronomer's observation of large scale structure to probe inflation and hence the fundamental interactions

What is a 'model of inflation'?

Model = OUTER SHELL ($V(\phi)$)

+ INTERIOR (underlying supergravity theory)

complete model
eg. "D-term inflation"

just a shell eg. "chaotic" inflation
$V \propto \phi^n$, $\phi \sim 10 M_p$

just an interior

THIS TALK:
PRECISE POTENTIAL NOT SPECIFIED

Keeping the inflaton potential flat

Use a global susy flat direction, but also need during inflation

INFLATON MASS

$$\left| \frac{m^2 M_P^2}{V} \right| \lesssim 0.1$$

INFLATON POTENTIAL

↑ from spectral index $|n-1| < 0.2$

$$\left(\frac{n-1}{2}\right) < 0.1$$

Supergravity with F term dominating

$$V = e^{K/M_P^2} [\ \cdots\ ]$$

$$K = |\phi|^2 + \cdots$$

$$\frac{m^2 M_P^2}{V} = 1 + X$$

Generically $|X| \gtrsim 10^{-1}$ or so

but we need $X = -1.0 \pm 0.1$

HOW?

Ways of keeping inflaton mass small

1. Hybrid inflation with Fayet-Iliopoulos term:

   D-term dominates potential

   [Stewart 95, Binetruy-Dvali 96 Halyo 96
   --- Uncle Tom Cobeby and all]

   - $\phi \gtrsim M_P$ so non-renormalizable terms out of control [Kolda/March-Russell]
   - V too big
   - Fields tend to drive $D \to 0$

2. Kinetic term diverges [Stewart 95] ??

3. Inflaton mass runs with scale 

   [Stewart 96, Covi/Lyth/Roszkowski 97]

4. Inflaton mass small by accident 

5. Inflaton mass small by design,

   no-scale type theory

   THIS TALK

??

Weakly coupled string theory

Gives dilaton/axion, bulk moduli, matter fields. Assume 3 moduli

$$t_I \qquad I = 1, 2, 3$$

matter fields

$$\phi_\alpha \qquad \alpha = AI \quad \text{(untwisted)}$$
$$\alpha = A \quad \text{(twisted)}$$

(dilaton/axion later)

Invariance under modular transformations gives superpotential

$$W = \sum_m \lambda_m \Pi_\alpha \phi^{n_m^\alpha} \Pi_I \eta(t_I)^{2\sum_\alpha \eta_m^\alpha q_I^\alpha - 2}$$

q_I^α = modular weight, $q_I^{AJ} = \delta_J^I$

$$K = -\sum_I \ln\left(t_I + t_I^* - \sum_A |\phi_{AI}|^2\right)$$

+ TWISTED

Recipe for successful inflation

During inflation require

every term of $W \simeq 0$

$$\Rightarrow \frac{\partial W}{\partial t_I} \simeq 0$$

twisted fields $< O(M_P)$

AND $$W_\alpha \equiv \frac{\partial W}{\partial \phi_\alpha} = 0$$

except for one untwisted sector

$$V = \frac{\sum_A |W_{AS}|^2}{x_1\ x_2} \qquad x_I \equiv t_I + t_I^* - \sum_A |\phi_{AI}|^2$$

This has no-scale form, but $V \neq 0$. Not obvious that masses small for flat directions of global susy. Need more detail to show this for at least one direction, to allow an inflaton.

Using a Fayet - Iliopoulos D term to generate the F term [GLM 98]

SIMPLEST MODEL

Assume only one nonzero W_α, $\alpha = C3$

coming from a term

$$W = \lambda \phi_{A1} \phi_{B2} \phi_{C3}$$

NO t_I DEPENDENCE!

generate ϕ_{A1}, ϕ_{B2} from FI D term

$$V_D = \frac{g^2}{2} \left(\xi - x_1^{-1} |\phi_{A1}|^2 - x_2^{-1} |\phi_{B2}|^2 + \cdots \right)$$

let A1, B2 be F-flat

$V_D \to 0$ gives

$$|\phi_{A1}|^2 = C_1 x_1$$

$$|\phi_{B2}|^2 = C_2 x_2$$

$$V \simeq \lambda^2 \xi^2$$

x_I dependence has gone!

flat directions preserved in all untwisted sectors, plenty of inflation candidates.

PROBLEMS OF D-TERM INFLATION AVOIDED

Including the dilaton

Assume $V^{1/4} \gg 10^{10}$ GeV

so that gaugino condensation negligible (?)

But we must stabilize the dilaton.

Use non-perturbative K, and linear multiplet formalism [BGW 97]

Simple scheme for inflation doesn't work.

Instead, allow more general form

$$W = \lambda \Phi_{c3} \left[\eta(t_1)\,\eta(t_2)\right]^{-2} \Pi_\alpha \Phi_\alpha \Pi_I \eta^{2q_I^\alpha}(t_I)$$

[$M_p = 1$] and generate some $\lambda \Phi_\alpha$ from D term and trigger the rest from other contributions to W.

CAN STABILIZE DILATON, AND

$$V \propto \Pi_I \left[\, |\eta(t_I)|^4 \, x_I \,\right]^{n_I}$$

$n_I = 0$ or $\pm$ INTEGER

NEED AT LEAST ONE $n_I = 0 \Rightarrow$ FLAT DIRECTIONS

OTHERS $< 0 \Rightarrow$ MODULI STABILIZED

MAGNITUDE $V \sim \lambda^2 (\zeta / M_p^2)^{\frac{d-1}{4}} \zeta^2$

CONCLUSION

Weakly coupled string theory may give viable inflation with FI D term generating an F term

Specific model ?

Connection with extensions of Standard Model ?

M - theory .... ?