Conformally Seized Moduli Inflation. S. Dimopoulos, F.T.

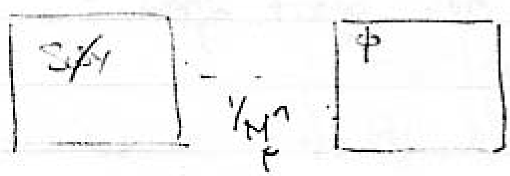
- Theories of inflation ... Small parameter
  $H^2/M_p^2 < 10^{-10}$

  Very Flat, Low Curvature, Small Self Coupling
  $\frac{d^nV(\phi)}{d\phi^n} \lesssim H^2 M_p^{2-n}$

- Susy:

  Natural Directions .. Moduli : V Vanishes in $\cancel{\text{Susy}}$

  $\cancel{\text{Susy}}$: $V(\phi) = m^2 M_p^2 f(\phi/M_p)$



← Generic feature.

← Most General Set of Cp.

Then for Generic f ..
Inequalities Saturated.

But typically Need Additional factor ~ 10^{-2}

{Hubble Scale mass/ η Problem} →

So SUSY Alone takes a long way to explaining small parameter -- but - -.

1. Could just find a UV Model - flat enough
   lot's of String Vacua

2. Search Mechanism: further 'flatens' $V(\phi)$

Requirements:

- Ingredients Generic (Not too Clever).
- Calculable in terms of Low Energy Theory
  - Small Field inflation . . .
    Renormalizable terms Only.
  - Large Field $\Delta\phi \gtrsim M_p$.
    i) Possible?
    ii) All Non-Renormalizable terms
- Predictive

Can - - Draw $V(\phi)$ - - Say Prediction.

Quantum Theory . . .

i) Q-Stable - -
ii) Finite # of Parameters . . .

Predictions in terms of

{ Here - Predictions actually turn out to be insensitive

· Motivation:

$$Z\, \partial\phi\, \partial\phi + V(\phi)$$

↳ Large Z Can Arise from Large γ
- - - - - - - from IR Dynamics.

Large Kinetic inertia 'Slows down' inflaton motion
(Seizes!) ↗ - —

- In terms of Canonically normalized field
Suppresses (Self) Couplings . . ∴ Flattens Potential

· Moduli + $V_{soft}(\phi)$

$\{ Z + \text{Vertex} \cdots \}$.

Even with 4Q - Exact Results for RG and SUSY

For V_{soft}:

i) Holomorphic terms - Closely Related . . .
ii) Non-Holomorphic . . Generally no.

but $m^2 \phi^\dagger \phi$ Special.

$$K \supset Z \phi^\dagger \phi \qquad Z = |Z| e^{\theta^2 \bar{\theta}^2 m^2}$$

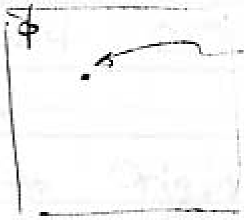
Extend β-fcns into Superspace. — Depend on derivatives

$$\beta_{\tilde{H}} = \Gamma(\tilde{H}) = \gamma(H) + \frac{\partial\Gamma}{\partial H}\tilde{H}$$

Don't Know These.

Super Conformal!: Know.

• How Get Large Renormalization effects on $\mathcal{M}$?



Generic feature:

Extra Matter massless at points on $\mathcal{M}$

Large Z

• Here focus on: Extra Matter forms CFT:

i) γ, γ' Constant: (vs ln) ⇒

RG effects Grow as Power law of IR Scale

ii) Know Strongly Coupled CFTs:

R.G effects Can be Large:

- Formally: Need Modulus to Control Magnitude of Relevant op. which drives CFT from fixed pt

UV —

↓

IR — $f(\phi)$

Gap.

Simplest Case case just Above: $m(\phi) = f(\phi)$

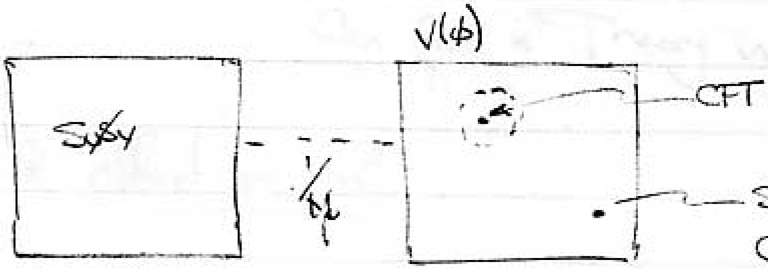
• CFT Sector:

D=4 CFT Requires Gauge Dynamics:

or $W = \phi Q \bar{Q}$

focus on This → · So Origin of C/H Branch

- Large Fraction of all $N=1$ Asym free GT $D=4$ Are CFT . . .



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SUSY Restored if Controls Coupling in SUSY Sector:

Aside:

So All Ingredients Completely Generic:

- Look at CFT point on $\mathcal{M}$ $\underline{V(\phi)}$.

$$V = V_0 + m^2 \phi^\dagger \phi + \cdots$$

i) Small Field
ii). m^2 Only Non-Holomorphic term Have Control over.

Can Get a Theory in terms of V_0, m^2.

RG $\underline{\text{effect on } m^2}$.

$$\begin{array}{lll} M & UV & m_0^2 \\ & \downarrow & \\ \mu & IR & m_g \propto \phi. \end{array}$$

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Finite Corrections
UV, IR - Absorb into M, m_0^2

$\beta = \beta_{m^2}$

$$m^2(\mu) = m_0^2 \left(\frac{\mu}{M}\right)^\beta$$
$$= m_0^2 \left(\frac{|\phi|}{M}\right)^\beta$$

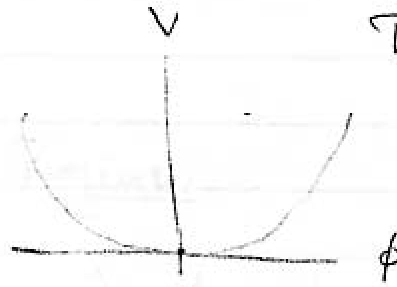
if CFT Attractive
$\gamma' > 0$ Mag of m^2 driven down

$\Rightarrow$

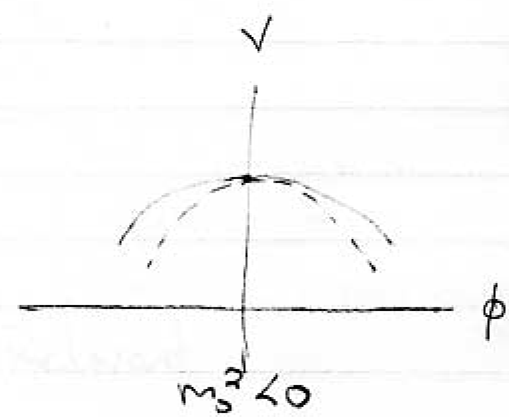
$$V = V_0 + m_0^2 \frac{|\phi|^{1+\beta}}{M^\beta} + \cdots$$

$\underline{\text{Flattening}}$.

Two Possibilities:



Requires $\phi \gg M_\phi$



$m_0^2 > 0$

$m_0^2 < 0$

Tachyonic - (Flows Away from Origin)

Can Analyze This

• Definite Example: CFT

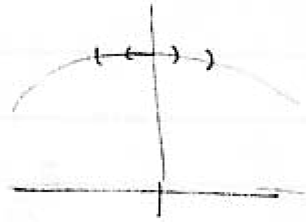
$SU(N_c) \qquad \frac{3}{2} N_c \le N_f < 3N_c$

$$M = Q\bar{Q}$$
$$B = Q \cdots Q$$
$$\bar{B} = \bar{Q} \cdots \bar{Q}$$

$$V = m_Q^2 \, Q^\dagger Q + m_{\bar{Q}}^2 \, \bar{Q}^* \bar{Q} + \underbrace{m_{Q\bar{Q}}^2}_{\text{Gets Larger.}} \, Q\bar{Q}$$

B or $\bar{B}$ Directions Have Flattened potentia

Inflation on



Regions:

i) $\phi \lesssim H$ CFT matter Relevant

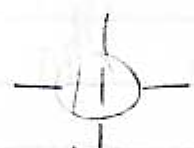
ii) Eternally inflating Regime -

$\dot{\phi}_{cl} \simeq -\dfrac{V'}{3H}$

$\langle |\dot{\phi}^2_{\phi}|^{1/2} \rangle \simeq H^2$

$\Bigg\} \quad \phi > \left(\dfrac{H^2}{m_0^2} \left(\dfrac{M}{H}\right)^{\beta} \right)^{1/(1+\beta)} H > H$

iii) HD Derivative terms:



$\partial\phi\, \partial\phi \dfrac{(\partial\phi\partial\phi)^n}{\phi^{4n}}$ Corrections $\sim \dfrac{\dot{\phi}^2}{\phi^4}$

in Classical Regime: $\dot{\phi} \lesssim H^2$

$\dfrac{H^2}{\phi^2} < 1$ inside Region i)

iv) $\dfrac{\delta\rho}{\rho} \sim \dfrac{H^2}{2\pi\dot{\phi}} \sim \dfrac{3}{(1+\beta/2)2\pi} \dfrac{H^2}{m_0^2} \dfrac{H}{\phi^{1+\beta}} M^{\beta}$

v) e-foldings:

$$N \sim \frac{3H^2}{(1+\beta/2)\, m_0^2} \left(\frac{M}{\phi}\right)^{\beta}$$

Doesn't depend on details of How inflation ends!

vi) H.O.T.

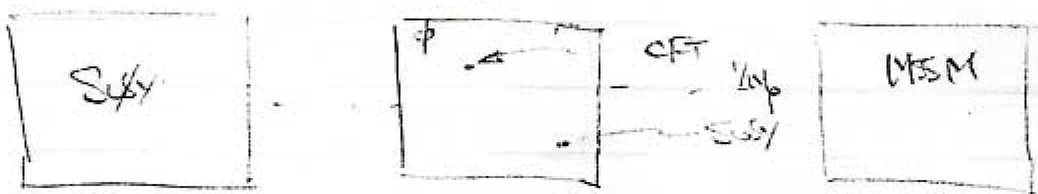
$$\frac{\tilde{m}_0^2}{M_p^2}\phi^4 \lesssim m^2\phi^2$$

$$\phi < \frac{m}{m_0} M_p \sim \frac{m_0}{\tilde{m}_0}\frac{\phi^\beta}{M^\beta} M_p$$

$$\phi < \left(\frac{m_0}{\tilde{m}_0}\frac{M_p}{M^\beta}\right)^{1/(1-\beta)}$$

Outside CFT Region Anyway

vii) End/ Reheating



$$\Gamma \sim \frac{H^3}{M_p^2}$$

Examples: $m^2 \sim H^2$ $\left(N \sim 60\,,\ \frac{\delta\rho}{\rho} \sim 10^{-5}\right)$

H	β_{m^2}	T_R
10^8 GeV	0,66	10^3 GeV
10^4 GeV	0,26	10^{-4} GeV (Direct Coupling to MSSM)

Predictions:

1. $\frac{\delta\rho}{\rho} \sim \frac{H^2}{2\pi \dot{\phi}}$ $\qquad \dot{\phi} \simeq \frac{V'}{3H}$

Small

$\therefore$

H small

$\therefore \quad r = \frac{T}{S}$ Unobservably Small.

2. Slope of spectral index: Adiabatic inflation

$n \simeq 1 - \frac{2(1+\beta_m^2)}{N_\phi}$ Red Spectrum.

Correlated

Allowed Range

(0.95 - 0.98).

3.

$\frac{dn}{d\ln K}$ Unobservably Small.

Conclude:

- Generic Mechanism.. flatten SUSY Moduli Potential:

- Ingredients Generic .. Not overly Clear:

- Predictive:

- Other App of Suppressed Soft mass:

1. Dark Energy Models:

$$10^{60} \sim \left(\frac{H_0}{M_p}\right)^{\beta}$$

$$\frac{10^{-33}\,\text{eV}.}{10\ \text{V}} = 10$$

$$m_0^2 \sim m m^{-1} \to m^2 \sim H_0 \qquad Z \sim 10^{30}$$

$$Z \sim \left(\frac{H_0}{M_p}\right)^{\beta = 1/2} \sim 10^{30}$$

(Say Solar System ...)

2. Very Long Range Subgravitational Forces:
Vid. EP:

3. EWSB: ?