Conformally Blocked Moduli Inflation

- Theories of inflation -- Small parameter
  \[ H^2/M_p^2 < 10^{-10} \]
  Very flat, low curvature, small self coupling
  \[ \frac{\phi^4}{\phi^2} \leq H^2 M_p^2 \]

- SUSY

  Natural Directions: Moduli: \( V \) Vanishes in \( SU(4) \)
  \( SU(4): V(\phi) = m^2 M_p^2 \phi^2(\phi/M_p) \)

  \[ \frac{\phi^4}{\phi^2} \leq H^2 M_p^2 \phi^2(\phi/M_p) \]

  Generic factor

  Most General Set of \( \phi \)

  Then for. Generic f...
  Inequalities Saturated:

  But typically need Additional factor \( \sim 10^{-2} \)

  {Hidden Scale mass/\( \eta \)}

  So SUSY alone takes a long way to explaining small parameter -- but --
1. Could just find a UV Model - flat enough
   lots of String Vacua

2. Search Medium: Further flatsens $V(\phi)$

   Requirements:
   - Ingredients Generic: (Not too clever)
   - Calculable in terms of Low Energy Theory
     - Small Field Inflation
     - Renormalizable terms only,
     - Large Field $\Delta \phi \sim M_P$
     - i) Possible?
     - ii) All non-renormalizable terms

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

   Quantum Theory...
   - i) Q-Stable
   - ii) Fine-tune Parameters
   --- Predictions in terms of
   Here - Predictions actually turn out to be inessential
Motivation:

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

1. Large $Z$ can arise from large $\phi$ from IR dynamics.

2. Large kinetic inertia "slow down" inflation motion (Seizes)

- In terms of canonically normalized field suppresses (Self) Couplings \( \Rightarrow \) Effective Potential

- Moduli + Vev $\phi$

\[ \{ Z + V \text{vertex} \ldots \} \]

Even with 4 $\phi$ - Exact Results for RG and SUSY

For Vev $\phi$:

i) Holomorphic terms - Closely Related

ii) Non-Holomorphic - Generally no

But $m^2 \phi \phi$ Special

\[ K = Z \phi \phi \quad Z = \frac{17}{e} \frac{m^2}{\phi} \]
Extend $\beta$-function into super-space, depend on derivatives.

\[ \beta_H = \gamma(H) = \chi(H) + \frac{2\chi}{H} \]

I don't know these.

Super conformal. I know.
• How get large Renormalization effects on $\lambda$?

• Generic feature:
  - Extra Matter massless at points on $\mathbb{R}$
  - Large $L$

• Here focus on: Extra Matter forms CFT:
  i) $\chi$, $\chi'$ constant:
    \[ \langle \sin \theta \rangle \]
    RG effects grow as Power law of $\mathbb{IR}$ scale
  ii) Know Strongly Coupled CFTs:
    RG effects can be large.

- Formally: Need Module to Control Magnitude of Relevant Op which drives CFT from fixed point $\mu$:

  \[ \mu \downarrow \]
  \[ \mathbb{IR} \downarrow f(\phi) \]
  \[ \text{Gap} \]
  
  Simplest case case just above $\mu$:
  \[ m(\phi) = f(\phi) \]
CFT Sector

D=4 CFT Requires Gauge Dynamics

- So Origin of Q/H Branch
- Large Fraction of all N=1 Asym Free GT D=4
Are CFT...

Aside

So All Ingredients Completely Generic
Look at CFT point on $M^2$ $V(\phi)$:

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

1) Small Field
2) $m^2$ Only Non-Holomorphic term that Controls $\phi$

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

RG effect on $m^2$.

$$M^2 \mu \rightarrow m^2$$

$$\mu \rightarrow \mu'$$

$$m^2(\mu') = m^2(\frac{\mu}{M})^{\beta}$$

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

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

- $\beta > 0$ Mag of $m^2$ driven down
- If CFT Attractive
- Flattening
Two Possibilities

\[ V \]

Requires \( \phi \rightarrow \eta' \)

\[ m_0^2 \eta' \]

\[ m_0^2 \eta ' \]

Tachyonic - (Flow Away From Origin)

Can Analyse This

- definite example: CFT

Solve \( \frac{3}{2} N_c \leq N_f \leq 3N_c \)

\[ M = 0 \Phi \]

\[ B = 0 \Phi \]

\[ \bar{\phi} = 0 \Phi \]

\[ V = m_0^2 \Phi \bar{\Phi} + m_3^2 \Phi^2 + m_0^2 \bar{\Phi} \]

\[ \text{gets larger} \]

\[ B \text{ or } \bar{B} \text{ directions have flattened potential} \]
Inflation:

Regions:

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

ii) Eternally Inflating Regime

$$\phi_{ee} = -\frac{V'}{3H}$$

$$\langle \phi^2 \rangle \approx H^2$$

$H > \frac{H^2}{\phi}$

iii) $H$ Derivative term

Correctors: $\frac{\dot{\phi}}{\phi}$

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

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

$\delta^2_{ee} \propto \frac{H^2}{\phi} + \frac{3}{\phi H^2 (H \phi^2 H^2 (H \phi^2 M^2)}$
v) e-foldings

\[ N_0 = \frac{2H^2}{(1 + \beta^2) m^2} \left( \frac{\phi}{\langle \phi \rangle} \right)^2 \]

Doesn't depend on details of how inflation ends.

vi) H.o.T.

\[ \frac{\dot{\phi}^2}{M_0^2} \phi^4 \leq m^2 \phi^2 \]

\[ \phi < \frac{m M_0}{M_0} - \frac{\dot{\phi}^2}{M_0^2} \phi \frac{M_0}{M^2} \]

\[ \phi < \left( \frac{m_0}{M_0} \right)^{\alpha(1-\beta)} \]

Outside CFT Region Anyway

vii) End/Review

\[ \begin{array}{c}
\text{SU(5)} \\
\text{CFT} \\
\text{MSM}
\end{array} \]

\[ \Gamma = \frac{1}{2} \left( \frac{\phi}{\langle \phi \rangle} \right)^2 \]
Examples: $m^2 - H^0 \quad (N=60, \quad \frac{\phi^0}{\phi} \cdot 10^{-3})$

$\begin{array}{ccc}
H & \beta_m & T_B \\
10^8 \text{ GeV} & 0.66 & 10^3 \text{ GeV} \\
10^4 \text{ GeV} & 0.26 & 10^4 \text{ GeV} \text{ (Direct Cavity)} \\
10^4 \text{ GeV} & 0.26 & 10^4 \text{ GeV} \text{ (MSM)}
\end{array}$
Predictions:

1. \[ \frac{\delta \rho}{\rho} = \frac{H^2}{2H} \phi \]
   \[ \phi = \sqrt{\frac{V}{2H}} \]

   \( A \) Small
   \( H \) Small

   \[ r = \frac{T}{\Omega} \text{ Unobservably Small} \]

2. Slope of spectral index: Adiabatic inflation
   \[ n = 1 - \frac{2(1 + B_\nu)}{N \nu} \]

   Red Spectrum: \( \text{Correlated} \) \( \text{Allowed Range} (0.95 - 0.98) \)

   \[ \frac{dn}{dlnk} \text{ Unobservably Small} \]
Conclude:

- Generic Mechanism: Flatness Moduli Potential
- Ingredients Generic: Not overly clever
- Predictive

- Other App of Suppressed Soft mass:

1. Dark Energy Models:

\[ A \times 10^{60} \left( \frac{\Lambda}{\Lambda_0} \right)^6 \]
\[ c = \frac{10^{-32}}{10^{-1}} \times 10^{-1} \]

\[ m_0 = \text{mm}^{-1} \rightarrow m_0 = H_0 \quad Z = 10^{30} \]

\[ Z = \left( \frac{H_0}{\Lambda_0} \right)^{1/2} = 10^{30} \]


3. Ewst?