Supersymmetric Inflation from the Fifth Dimension

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work in progress with

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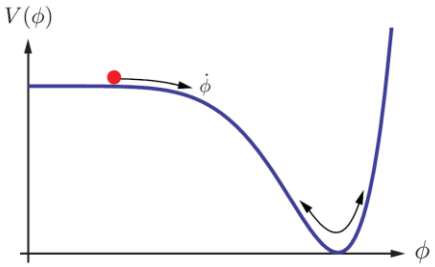
Background

- Cosmic inflation: $\mathrm{m}_{\phi}^{2} \sim \eta_V \, H_{inf}^{2}$, "hierarchy problem" for inflaton



- Natural inflation: inflaton as a Goldstone boson Freese et al. (1990)

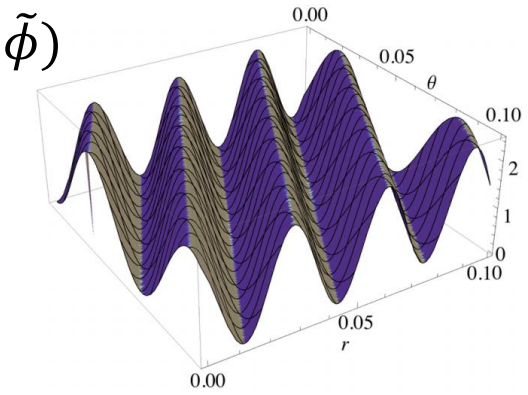
  $V(\phi) = V_0 \left(1 - \cos\frac{\phi}{f}\right)$... but requires $f \approx 10\, M_{pl}$! Planck (2015)

- Bi-(or Multi-)axion inflation: Kim, Nilles, Peloso (2005)

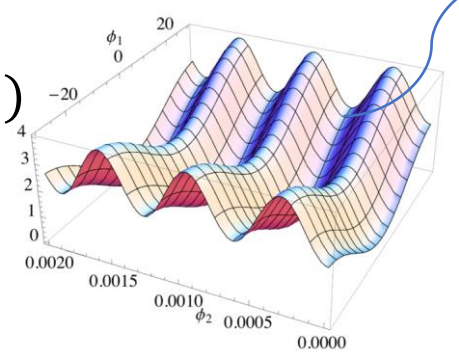
  $V(\phi, \tilde{\phi}) = V_0 \left(1 - \cos\frac{\tilde{\phi}}{\tilde{f}}\right) + \widetilde{V_0}\left[1 - \cos\left(\frac{\phi}{f} + \frac{N\tilde{\phi}}{\tilde{f}}\right)\right] \Rightarrow V(\langle\phi_h\rangle, \phi_l) \approx V_0 \left(1 - \cos\frac{\phi_l}{Nf}\right)$

Background… using 5D gauge symmetry

$V(\phi, \tilde{\phi})$



$V(\phi_l, \phi_h)$



inflationary trajectory

Ben-Dayan, Pedro, Westphal (2014)

Charges under A, B:

$(0,1), (1,N)$

Q_1, Q_2

$A_\mu\ , A_5$

$B_\mu\ , B_5$

$x_5 = 0$ $\quad$ $x_5 = L$

Bai et al. (2015), de la Fuente et al. (2015)

$$\phi \equiv \int_0^L A_5\, dx_5\ ,\ \tilde{\phi} \equiv \int_0^L B_5\, dx_5$$

$$V_0^{loop} \sim \frac{e^{-mL}}{L^4}\ ,\ V_0^{tree} \sim mvv' e^{-mL}$$

$Q_{1,2}$ boundary VEVs

Can this picture be supersymmetrized?

SUSY during inflation

- Motivation: SUSY surviving till low energies (1, 10, 1000 TeV)?
- SUSY by itself can't make inflaton light enough during inflation!

  broken during inflation, need shift symmetry for Φ_{inf}, $K(\Phi + \bar{\Phi})$ Kawasaki et al. (2000)
- Need tree-level $V_{eff}(A_5)$!

  SUSY loop cancellation, can get from non-trivial boundary VEVs of charged matter
- Physical requirements for inflation:

  - inflation end @ SUSY vacuum with $CC = 0$

  - inflationary trajectory as ~flat direction, stabilized, +ve vacuum energy, SUSY breaking

SUGRA bi-axion extranatural inflation

$$Q_1^{(0,1)}, Q_2^{(1,N)} \;\Big|\; \langle Q_{1,2}\rangle = v$$

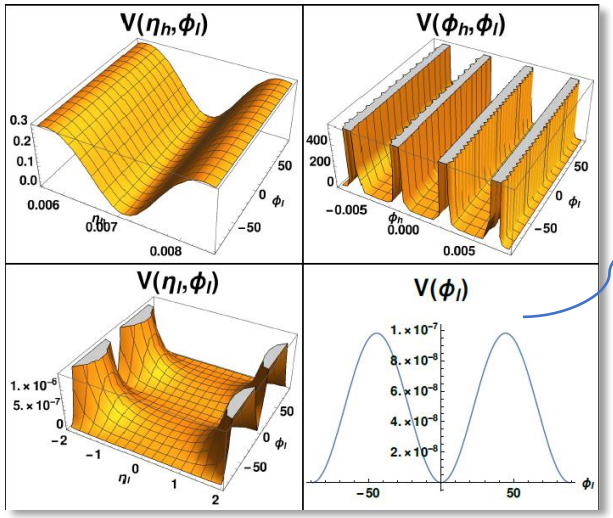
$$A_\mu, A_5 \;\Big|\; \langle A_\mu, B_\mu\rangle = 0$$
$$B_\mu, B_5$$

$$\Phi, \tilde{\Phi}$$

$$K = \frac{1}{2}(\Phi + \bar{\Phi})^2 + \frac{1}{2}\left(\tilde{\Phi} + \bar{\tilde{\Phi}}\right)^2$$

$$W = W_0 - \frac{2v^2}{e^{mL}\, e^{-\frac{gL}{\sqrt{2}}(\Phi + N\tilde{\Phi})} + inv.} - \frac{2v^2}{e^{mL}\, e^{-\frac{gL}{\sqrt{2}}\tilde{\Phi}} + inv.}$$

$$V_{SUGRA}^{scalar}(\Phi, \tilde{\Phi}) = e^K[|D_\Phi W|^2 + |D_{\tilde{\Phi}} W|^2 - 3|W|^2]$$



$$V_{eff}(\phi_l) \approx \frac{H_{inf}^2}{2}\left(1 - \cos\frac{\phi_l}{f_{eff}}\right)$$

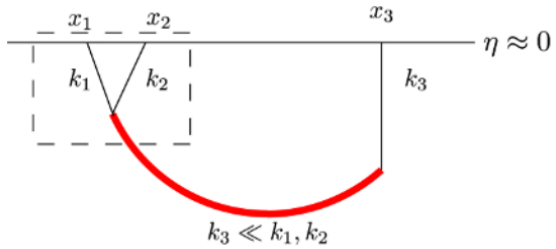
$$; H_{inf} \approx 4\sqrt{\frac{2}{3}}\frac{v^2 e^{-mL}}{f}, f_{eff} = Nf$$

Surprising feature… SUSY breaking during inflation by mostly the heavy sector!

c/w Ferrara, Kallosh, Thaler (2016)

Observable signals

- Primordial non-Gaussianities: Chen, Wang (2010), …



  - sinflaton (η_l)

    $m_{\eta_l} \approx \sqrt{6}\, H_{inf}$, $\eta_l \phi_l \phi_l$ coupling $\approx 10^{-3} \frac{H_{inf}}{M_{pl}} H_{inf}$ $\Rightarrow$ no observable NG $(f_{NL} \lesssim 10^{-6})$!

  - brane-localized gauge singlet (X)

    $m_X \approx \sqrt{3}\, H_{inf}$, $\frac{c}{\Lambda}\, \eta_X \left(\partial_\mu \phi\right)^2$ $\Rightarrow$ observable NG $(f_{NL} \gtrsim 10^{-2})$!

- Periodic modulations in CMB:

  massive charges near cutoff, "higher harmonics" in $V(\phi_{inf})$

  modulations in CMB power spectrum with $\frac{\delta\epsilon}{\epsilon} \approx 1 - 5\%$, allowed by data

Flauger et al. (2017)
de la Fuente et al. (2015)

Conclusions

- Compatibility of SUSY with Natural Inflation

  - inflaton potential protected by 5D origin of axions

- Tree-level $V_{eff}(A_5, B_5)$ from charged matter VEVs

  - needed due to SUSY loop cancellations

- Viable inflation model, central features from 5D gauge dynamics

  - SUSY breaking during inflation mostly by the heavy sector!

- Fine-tuning related to the CC problem… familiar in SUGRA/string theory context, no extra

- Observable signals

  - primordial NG: sinflaton ✗ (very small coupling), brane-localized singlet ✓ (thru' derivative coupling)

  - periodic modulations in the CMB