Natural Inflation and Low Scale Supersymmetry

Rolf Kappl

Bethe Center for Theoretical Physics & Physikalisches Institut der Universität Bonn

based on RK, Hans Peter Nilles and Martin Wolfgang Winkler
arXiv:1503.01777, Phys.Lett. B746 (2015) 15-21

String Phenomenology 2015 Madrid, June 9th 2015

Outline

Motivation

- Assumption 1: LHC will find low scale supersymmetry $\Rightarrow m_{3/2} \approx \mathcal{O}(1 \ldots 100)$TeV
- Such a low Gravitino mass results in a small superpotential in the minimum $\Rightarrow \langle W \rangle = W_0 \approx 10^{-10}$
- Assumption 2: A large scalar-to-tensor ratio $r = \mathcal{O}(0.01)$ will be discovered
- This results in a large Hubble scale during inflation $\Rightarrow H \approx 10^{-4}$
- A large Hubble scale would favor a model like natural or chaotic inflation

How can we find a string-inspired model with small W_0 and large H?

Natural inflation for large r and large H

- Natural inflation [Freese, Frieman, Olinto, 1990] is inflation with one axion
- Axion has a continous shift symmetry
- Non-perturbative effects break the shift symmetry to a discrete symmetry
- Small breaking induces a flat potential sufficient for inflation
- Flatness is controlled by the symmetry breaking

Axion is a natural inflaton candidate with potential

$$V(\varphi) = \Lambda^4 \left(1 - \cos\left(\frac{\varphi}{f}\right)\right)$$

Natural inflation and high scale supersymmetry breaking

- Simple model with $W = W_0 + Ae^{-a\rho}$ and $K = \frac{1}{4}(\rho + \bar{\rho})^2$
- The non-perturbative term in W breaks the shift symmetry and $\mathrm{Im}(\rho)$ can be used as inflaton
- Without large W_0 this model results not in the correct scalar potential for natural inflation
- If $W_0 \gg Ae^{-a\rho}$ we can integrate out the stabilized saxion $\mathrm{Re}(\rho)$ and get the correct potential after an uplift with $V_{\mathrm{up}} \sim \mathcal{O}(W_0^2)$
- The large constant W_0 needed for the uplift results in high scale supersymmetry breaking

If the LHC will find supersymmetry this class of models is ruled out!

Natural inflation and preserved supersymmetry

- $W = m^2 X(e^{-a\rho} - \lambda)$ and $K = \frac{1}{4}(\rho + \bar{\rho})^2 + k(|X|^2)$
- The scalar potential is ($\rho = \rho_0 + \chi + i\varphi$)

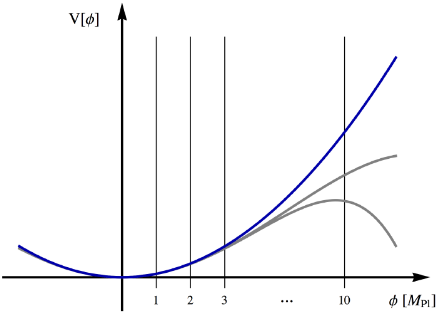
$$V = 2m^4 e^{(\rho_0+\chi)^2 - a(2\rho_0+\chi)} \left(\cosh(a\chi) - \cos(a\varphi)\right)$$

- $\mathrm{Im}(\rho) = \varphi$ is again the inflaton and there is a supersymmetric minimum for $X_0 = 0$ and $\rho_0 = -\frac{\log(\lambda)}{a}$
- In the minimum $m_\chi = m_\varphi$ due to supersymmetry, but the saxion is trapped through the exponential e^K in V.
- This potential realizes natural inflation (large r and H) with unbroken supersymmetry at the end of inflation

If the LHC will find supersymmetry and r is large this class of models is very good

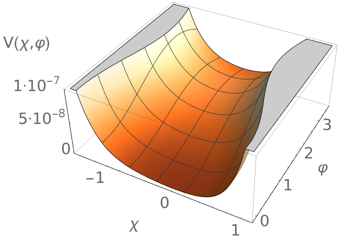
Problems within string theory

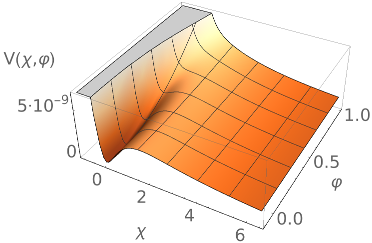
- $N = 60$ e-folds require trans-Planckian field ranges $\Delta\varphi > M_{\text{Planck}}$
- This implies also a trans-Planckian axion decay constant $f > M_{\text{Planck}}$
- This is problematic for an effective field theory description as well as for a string theory embedding



Moduli stabilization problems within string theory

- Kähler potential in string theory more likely $K = -\log(\rho + \bar{\rho})$
- Saxion stabilization is much more difficult because of the runaway direction





Solution with aligned natural inflation

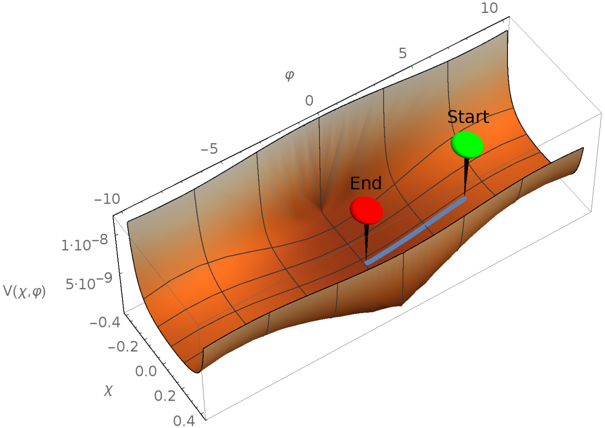
- A second axion solves the problem with the trans-Planckian decay constant as well as the problem with the saxion stabilization
- Inflation along a trajectory of two misaligned axions results in an effective trans-Planckian decay constant [Kim, Nilles, Peloso, 2004] sufficient for natural inflation
- We consider a two axion (ρ_i) model with matter fields (X_i)

$$W = \sum_{i=1}^{2} m_i^2 X_i (e^{-a_i \rho_1 - b_i \rho_2} - \lambda_i)$$

$$K = -\sum_{i=1}^{2} \log(\rho_i + \bar{\rho}_i) + k(|X_i|^2)$$

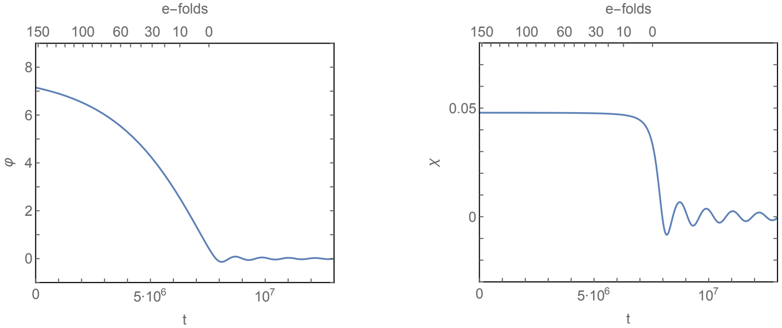
Natural parameters for natural inflation

a_1	b_1	a_2	b_2	m_1	m_2	λ_1	λ_2
$\frac{7\pi}{6}$	$\frac{8\pi}{7}$	$\frac{6\pi}{7}$	$\frac{7\pi}{8}$	0.45	0.55	$2.6 \cdot 10^{-4}$	$2.0 \cdot 10^{-3}$



Stabilized saxion and successful inflation

- The light saxion combination (χ) is stabilized because the Kähler metric has two poles between which the saxion is trapped
- Inflation happens along the light axion direction (φ) without spoiling moduli stabilization



Conclusions

- Low scale supersymmetry together with high scale inflation is possible
- Aligned natural inflation with matter fields leads to low scale supersymmetry with successful moduli stabilization

Thank you for your attention!