Why String Inflation?

Sebastian Halter

Max-Planck-Institute for Physics, Munich

IMPRS/GK Young Scientists Workshop 2010,
Ringberg Castle

July 28th, 2010

Outline

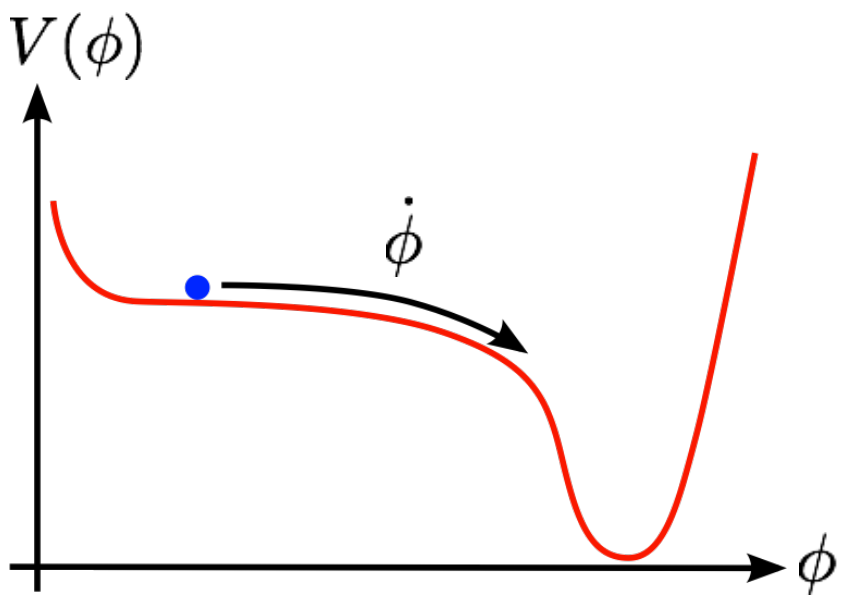
1. The Eta-Problem of Inflation
2. Solution in Effective Field Theory
3. Black Holes & Quantum Gravity
4. Inflation in String Theory
5. Summary

1. The Eta-Problem of Inflation

Basic Idea: scalar field slowly rolling down its potential

Slow-roll inflation characterized by 3 parameters

$$H^2 \sim \frac{V}{M_P^2} \ , \ \epsilon \sim M_P^2 \left(\frac{V'}{V}\right)^2 \ , \ \eta \sim M_P^2 \frac{V''}{V}$$



Theoretical requirement:

$$\epsilon \ll 1 \quad , \quad |\eta| \ll 1$$

Experimental constraint:

$$|\eta| \lesssim 10^{-2}$$

1. The Eta-Problem of Inflation

In terms of effective field theory:

Problem with two scales:

a) cutoff of the field theory H

b) mass of the scalar field m_ϕ^2

$\Rightarrow$ Eta parametrizes the hierarchy between these scales

$$\eta \sim \frac{m_\phi^2}{H^2}$$

But: scalar masses have a large UV sensitivity.

1. The Eta-Problem of Inflation

Indeed: dimension 6 operators generically spoil slow-roll inflation.

Consider operators of the form

$$\mathcal{O}_6 \sim \frac{1}{M_P^2}\mathcal{O}_4\phi^2 \quad , \quad \langle \mathcal{O}_4 \rangle \sim V$$

$\Rightarrow$ Correction to inflaton mass:

$$\Delta m_\phi^2 \sim H^2 \quad \Rightarrow \quad \Delta\eta \sim 1$$

$\Rightarrow$ A light inflaton is radiatively unstable.

2. Solution in Effective Field Theory

How to solve this issue ‘naturally’?

Typically: light particles related to approximate symmetries

Examples:

a) light Higgs due to supersymmetry

b) light pions from chiral symmetry breaking

Can supersymmetry solve the eta-problem?

No, it is strongly broken during inflation.

$\Rightarrow$ Let’s try an approach similar to pions.

2. Solution in Effective Field Theory

Inflaton = Pseudo-Nambu-Goldstone-Boson (PNGB) of a spontaneously broken approximate global symmetry

[Freese, Frieman, Olinto '90]

Example: a global U(1) symmetry

$\Rightarrow$ inflaton has a shift symmetry

$$\phi \rightarrow \phi + const$$

$\Rightarrow$ exactly flat potential, i.e. massless field

Break U(1) in a controlled way, e.g. by 1-loop corrections.

$\Rightarrow$ 'naturally' small inflaton mass

$\Rightarrow$ Then why string inflation?

3. Black Holes & Quantum Gravity

A 'generic' theory of quantum gravity does NOT respect any continuous global symmetry.

[Kamionkowski, March-Russell '92; Holman, Hsu, Kephart, Kolb, Watkins, Widrow '92; Kallosh, Linde, Linde, Susskind '95]

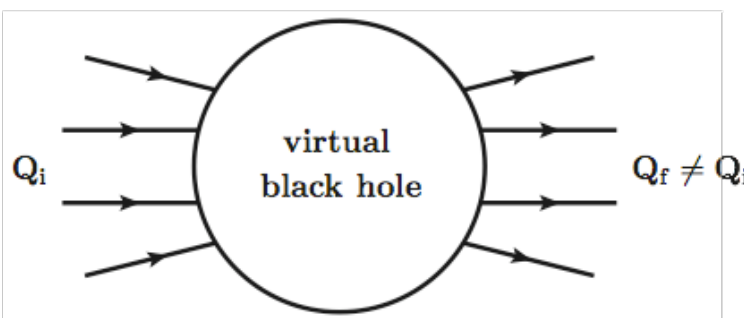
Consequence of 'no-hair' theorem: black holes...

a) ... are fully characterized by mass, spin and electric charge

b) ... carry no well-defined charge under any global symmetry

Consider scattering process involving virtual black holes.

$\Rightarrow$ black holes evaporate and produce final state of different charge



3. Black Holes & Quantum Gravity

In terms of effective field theory:

Symmetry breaking described by Planck-suppressed higher-dimensional operators

$$\frac{c}{M_P^{d-4}}\mathcal{O}_d \quad , \quad c \sim \mathcal{O}(1)$$

$\Rightarrow$ Eta-problem reintroduced by quantum gravity effects

What to do now?

$\Rightarrow$ consider a theory of quantum gravity & matter

$\Rightarrow$ realize inflation in string theory

4. Inflation in String Theory

String theory has many moduli, i.e. classically flat directions.

Two classes of moduli as inflaton:

a) open string sector: brane positions [Dvali, Tye '98]

b) closed string sector: size and shape of compact space [Binetruy, Gaillard '86; Banks, Berkooz, Moore, Shenker, Steinhardt '95]

Moduli of type b) control couplings of low energy theory.

$\Rightarrow$ need to be stabilized during and after inflation

Example: 4D Planck scale governed by overall volume

$$M_P^2 \sim M_{10}^8 R^6$$

4. Inflation in String Theory

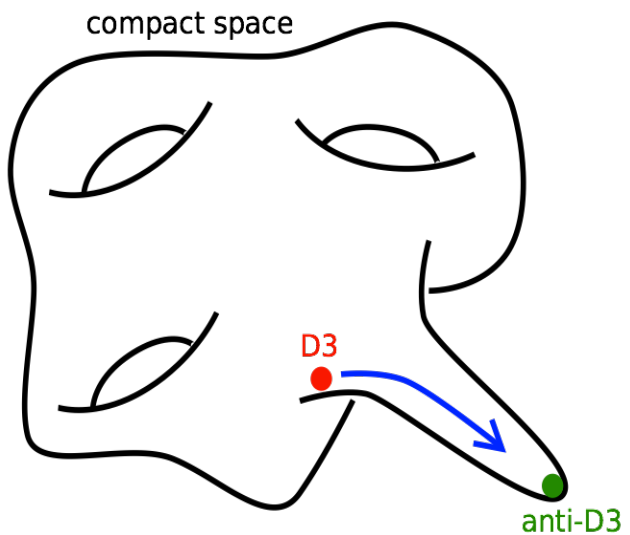
Examples & geometric interpretation:

a) warped brane inflation:

inflation = branes moving around in compact space

end of inflation = branes annihilating each other

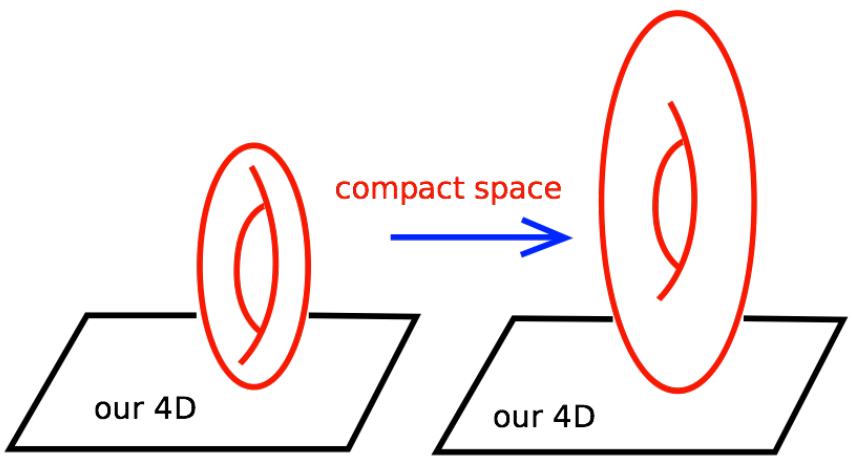
$\Rightarrow$ inflaton disappears



[Kachru, Kallosh, Linde, Maldacena, McAllister, Trivedi '03]

b) volume modulus inflation:

inflation = overall size of compact space changing



5. Summary

Inflation generically suffers from its UV sensitivity

$\Rightarrow$ Light inflaton is radiatively unstable

Effective field theory: inflaton as PNGB of approximate global symmetry

$\Rightarrow$ Inflaton can be ‘naturally’ light

Quantum gravity effects generically do not respect any global symmetries

$\Rightarrow$ Realize inflation in string theory

Problem: Moduli stabilization might spoil string inflation

$\Rightarrow$ Eta-problem reintroduced?