Title: Flattening the Landscape

Date: Oct 26, 2005 05:00 PM

URL: http://pirsa.org/05100056

Abstract:

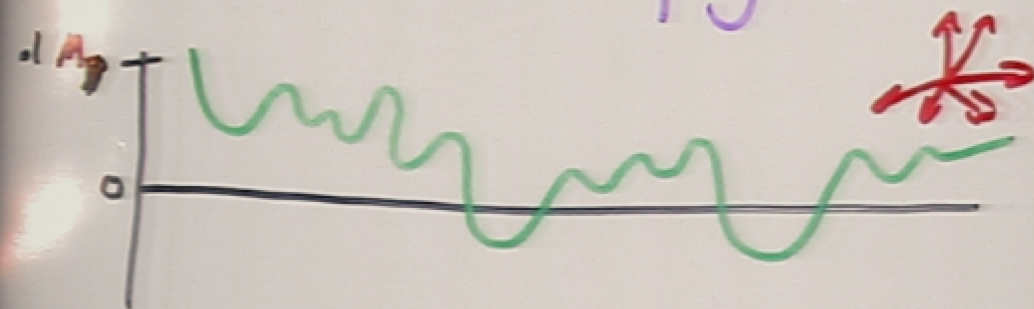
FLATTENING the Landscape

Matthew Kleban
IAS

hep-th/0505232 — Freivogel, Rodriguez Martinez, Susskind

in progress — Batra, Rabadan

Want to use the landscape to describe physics



low energy physics in each minima differs:

cosmo. constant, gauge groups, particle masses, etc.

hard to compute!

What about cosmology?

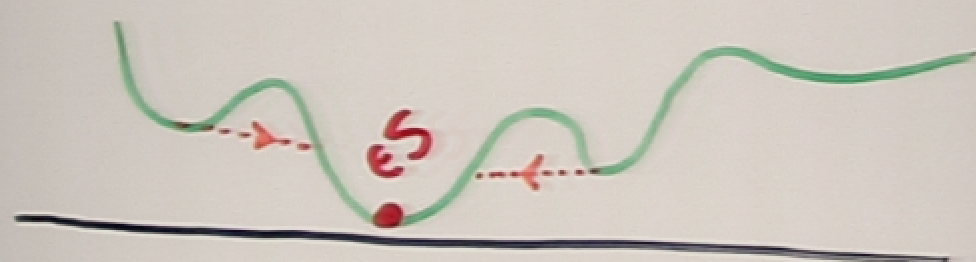
Assumptions

- $\exists$ a set S of minima consistent with observed particle physics

- landscape is populated by tunnelling – provides some Knowledge of cosmo initial conditions

Given a starting point, most of the landscape can be populated with only a few "jumps."

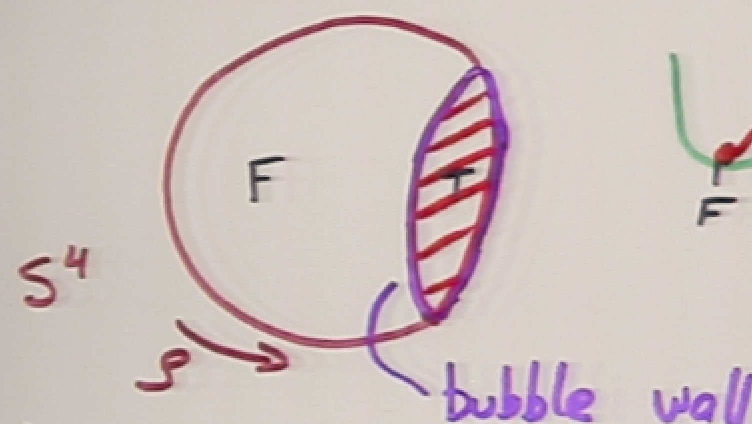
So consider our set S.
How many ways to tunnel in?

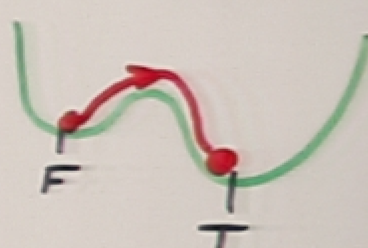


Good cosmology?

Consider one type of tunnelling: Coleman-de Luccia

Saddle point of the action with $O(4)$ symmetry

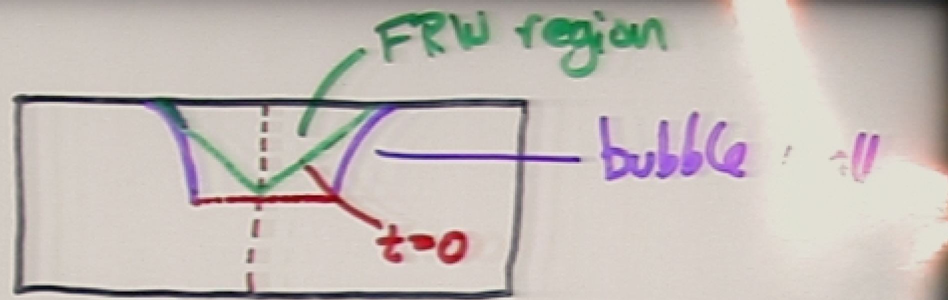


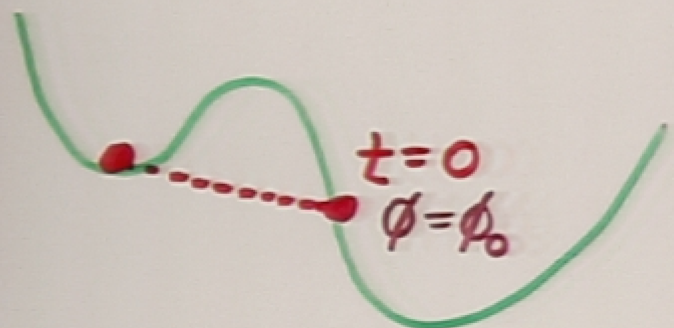


$$ds_E^2 = d\rho^2 + f^2(\rho)\, d\Omega_3^2 \longleftarrow O(4)$$

$$\longrightarrow ds^2 = -dt^2 + a^2(t)\, dH_3^2 \longleftarrow O(3,1)$$

Open Universe





initial conditions:

$$\phi = \phi_0 \qquad a = t + \mathcal{O}(t^3)$$

$$\dot{\phi} = 0 \qquad \text{(curvature dominated)}$$

non-singular big bang!

Very homogeneous space - no structure

Universe is not only very homogeneous, it's open

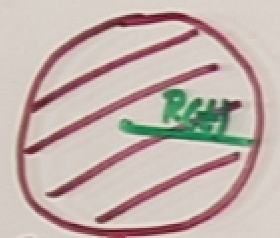
expanding faster than necessary to avoid collapse

→ overdense regions must be more overdense than in a flat universe in order to collapse & form structure

effect is similar to that of $\Lambda > 0$

Consider an overdense region in a MD open universe:

$R(t)$



ρ, K

$\rho + \delta\rho$
$K + \delta K$

evolution governed by Friedmann eq.:

$$\dot{R}^2 + K + \delta K = \frac{8\pi G}{3} R^2 (\rho + \delta\rho) + \frac{\Lambda}{3} R^2$$

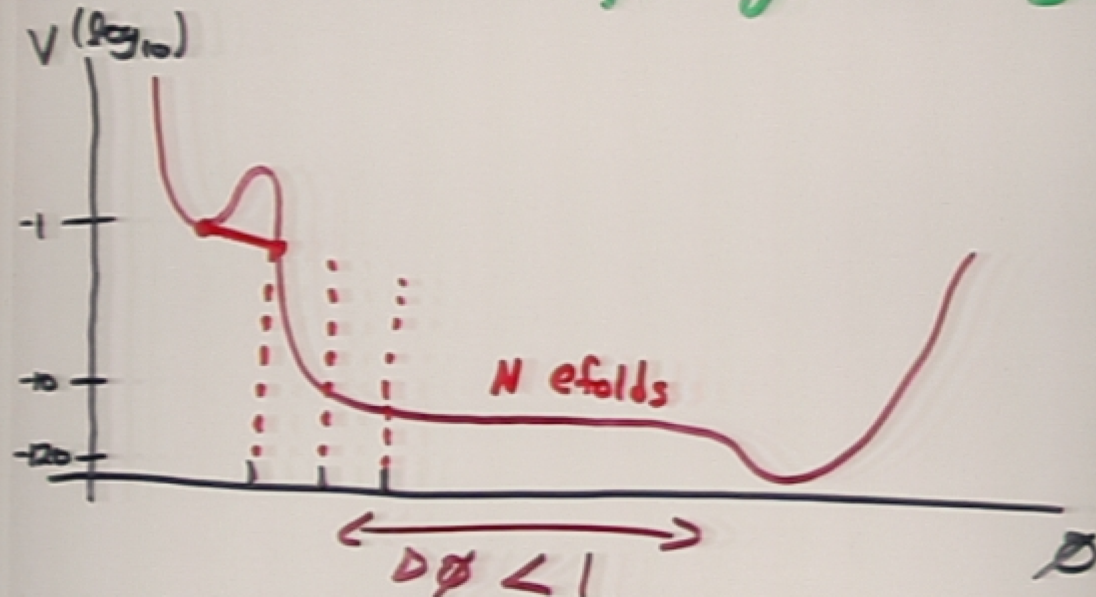
Under what conditions does $R(t) \to 0$?

Weinberg

Before analyzing this ϵ,
think what is needed

universe is highly curved, $\delta\xi \sim O$

need a mechanism to reduce
the curvature, & generate $\delta\xi$



No overshoot problem (due to curv.)

Strategy: fix $\delta\rho/\rho \sim 10^{-5}$,

then use requirement of structure to fix N, curvature

amount of expansion between end of inflation & decoupling depends only weakly on $V(\phi)$

since we know the curvature at beginning of inflation, a bound on curv. today

$\rightarrow$ bound on N: $N > N_c$

Strategy: fix $\delta\rho/\rho \sim 10^{-5}$,
then use requirement of structure to fix N, curvature

amount of expansion between end of inflation & decoupling depends only weakly on $V(\phi)$

since we know the curvature at beginning of inflation, a bound on curv. today

$\rightarrow$ bound on N: $N > N_c$

$$\boxed{\frac{3}{2^{2/3}}\left(\frac{\Omega_\Lambda}{\Omega_m}\right)^{1/3} + \frac{1-\Omega_t}{\Omega_m} \leq \frac{5}{3}\frac{\delta_3}{g}}$$

In our universe today, this is satisfied on scales

$$L < L_c \sim 5 \text{ Mpc}$$

Structures smaller than L_c will continue to collapse; those larger will never collapse (assuming dark energy = Λ)

The observational bound on

Ω_t is $\Omega_t > .98$ (1σ)

Plugging in typical #'s for reheating etc., $\rightarrow$ $\boxed{N_0 \gtrsim 62}$

What does the structure bound imply for a universe with the same reheating temp?

$$\boxed{N_s > 59.5}$$ (dwarf galaxies)

not bad... how likely is that in the landscape?

The observational bound on Ω_t is $\Omega_t > .98$ (1σ)

Plugging in typical #'s for reheating etc., $\rightarrow$ $\boxed{N_o \gtrsim 62}$

What does the structure bound imply for a universe with the same reheating temp?

$$\boxed{N_s > 59.5}$$ (dwarf galaxies)

not bad... how likely is that in the landscape?

to answer, need a measure on landscape potentials

so far, doesn't exist

toy model: linear potential

$$V(\phi) = V_0 \left(1 - x \frac{\phi}{\Delta}\right)$$

$\phi \in [\phi_i, \phi_f]$, $\Delta = \phi_f - \phi_i$

assume V_0, x, Δ vary for 0, 1 with a smooth measure F

$$P(N) = \frac{2}{5} \frac{\delta\rho/\rho}{N^4} \quad (\text{for } F = 1)$$

• So $P_{N>62} = \int_{62}^{\infty} P(N)\, dN \sim 10^{-12}$

(using $\delta\rho/\rho \sim 10^{-5}$)

"flatness problem"

But $\dfrac{P_{N>62}}{P_{N>59.5}} \sim .9$

Solution?

Note: these P's were computed only from $V(\phi)$

they don't include volume factors: i.e. more inflation → more volume

Vilenkin

open question how to handle that

Signatures

- Curvature

  problem: if $P(N)$ is too smooth, likely that $N \gg N_s$

- CMB spectrum

  problem: as above

- Measure on inflaton potentials

  problem: hard – but may be possible

Signatures

- Curvature

problem: if $P(N)$ is too smooth, likely that $N \gg N_s$

- CMB spectrum

problem: as above

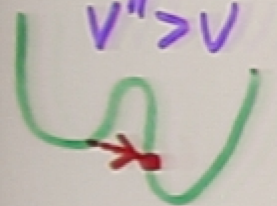
- Measure on inflaton potentials

problem: hard - but may be possible

in progress: (Bat Rebol

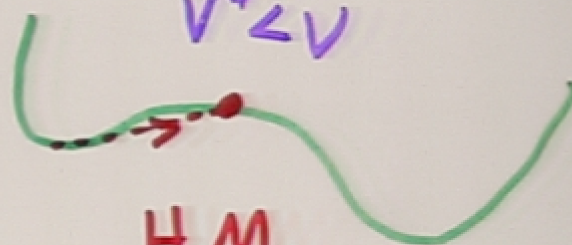
CdL instantons don't always exist

$V'' > V$



CdL

$V'' < V$



HM

Hawking-Moss instantons have quite different (but still characteristic) initial conditions

Conclusions

the string theory landscape could make testable predictions for cosmo, e.g. curvature

many directions to pursue

need some understanding of the measure on inflaton poten.

Must understand the measure problem