On String Cosmology and the Swampland

(discussion session with Gary Shiu)

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Back to the Swamp
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Realistic string models and the needle in a haystack

Different approaches

Brute force

Top down

Bottom up

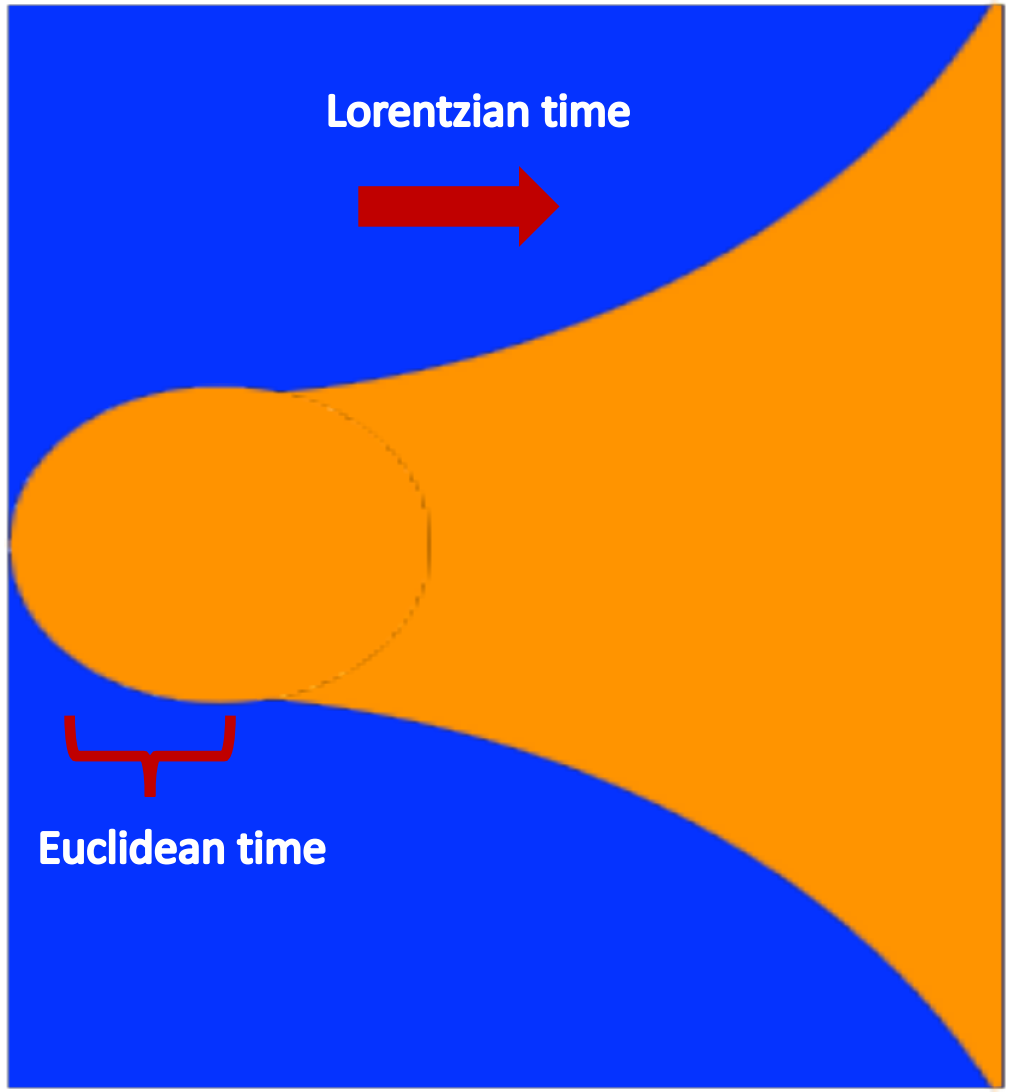
Swamp land

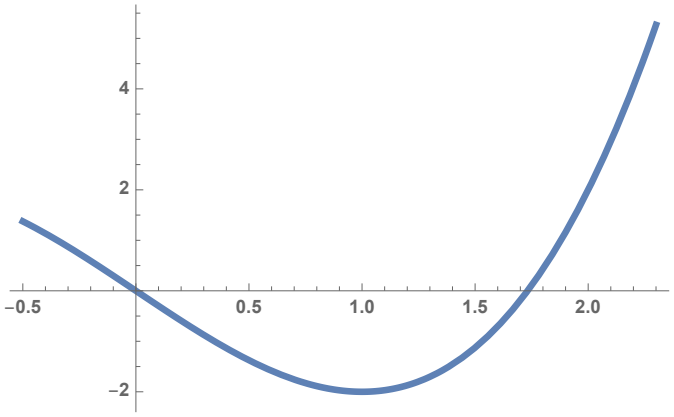
Pre-strings quantum cosmology
(semiclassical gravity)

Open questions

- Origin of spacetime
- Big bang and before?
- Source of density perturbations
- Naturalness problems
- Acceleration of the universe
- Realistic spectrum and couplings

Wave function of the universe





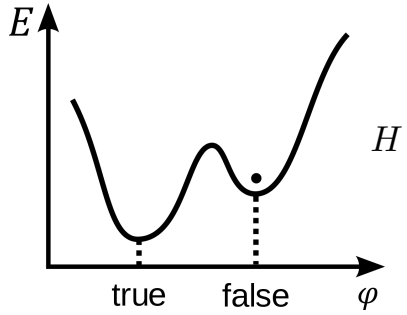
$$\mathcal{H} = -\frac{\pi_a^2}{12a} - 3a + a^3\Lambda$$

Wheeler-DeWitt, Vilenkin, Hartle-Hawking

Vacuum Transitions
(beginning and end of our universe?)

1. **Transition between two minima of scalar potential**

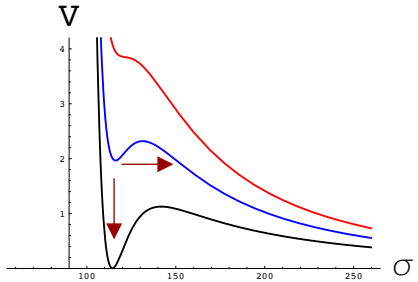
   Coleman-De Luccia 1980

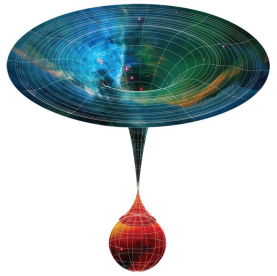


$$H = \int_X \left[\frac{\pi_\phi^2}{2} + \frac{1}{2}\nabla_x^2\phi + V(\phi) \right] = E\,,$$

2. **Brane nucleation: M_1 to M_1+Wall+M_2**

   Brown-Teitelboim 87





3. **Hamiltonian approach**

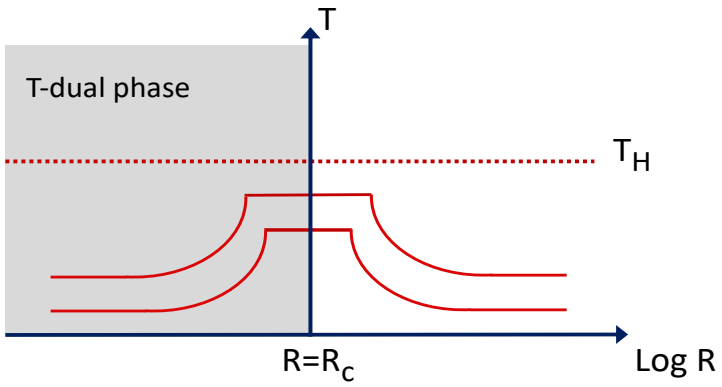
   Fischler-Morgan-Polchinski 1988

String Theory and Cosmology

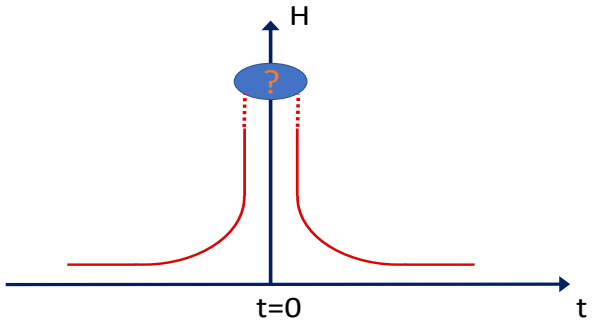
Forthcoming review:
Cicoli, Conlon, Maharana, Parameswaran, FQ, Zavala

String cosmology

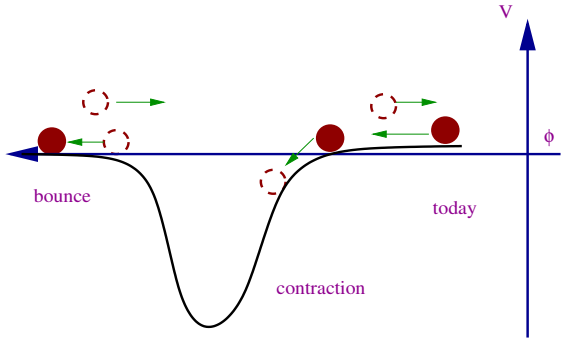
String gas



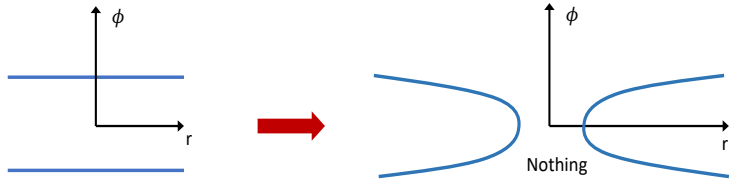
Pre big-bang



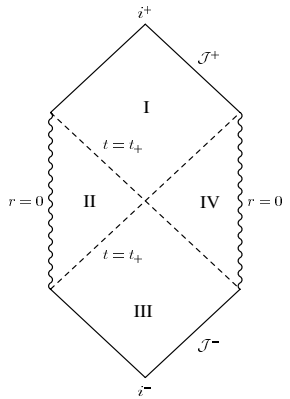
Ekpyrotic /cyclic



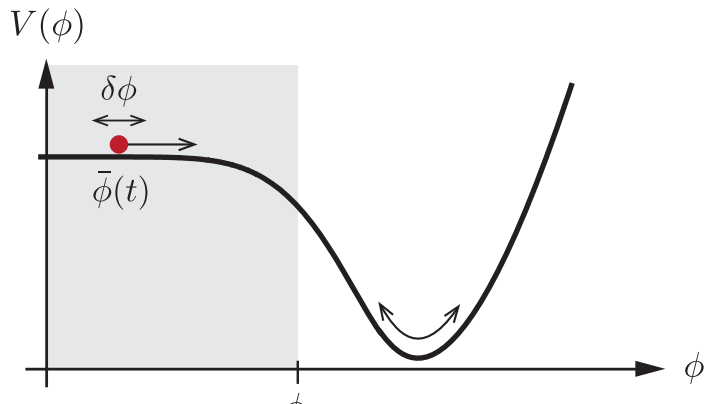
Bubble of nothing



S-branes/ Rolling tachyons



String inflation



Concrete Models of String Inflation

String Scenario	n_s	r
$D3/\overline{D3}$ Inflation	$0.966 \leq n_s \leq 0.972$	$r \leq 10^{-5}$
Inflection Point Inflation	$0.92 \leq n_s \leq 0.93$	$r \leq 10^{-6}$
DBI Inflation	$0.93 \leq n_s \leq 0.93$	$r \leq 10^{-7}$
Wilson Line Inflation	$0.96 \leq n_s \leq 0.97$	$r \leq 10^{-10}$
D3/D7 Inflation	$0.95 \leq n_s \leq 0.97$	$10^{-12} \leq r \leq 10^{-5}$
Racetrack Inflation	$0.95 \leq n_s \leq 0.96$	$r \leq 10^{-8}$
$N-$ flation	$0.93 \leq n_s \leq 0.95$	$r \leq 10^{-3}$
Axion Monodromy	$0.97 \leq n_s \leq 0.98$	$0.04 \leq r \leq 0.07$
Kahler Moduli Inflation	$0.96 \leq n_s \leq 0.967$	$r \leq 10^{-10}$
Fibre Inflation	$0.965 \leq n_s \leq 0.97$	$0.0057 \leq r \leq 0.007$
$Poly-$ instanton Inflation	$0.95 \leq n_s \leq 0.97$	$r \leq 10^{-5}$

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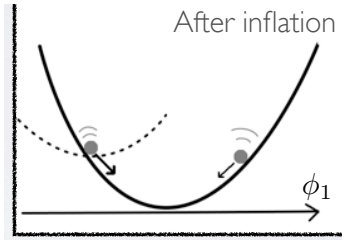
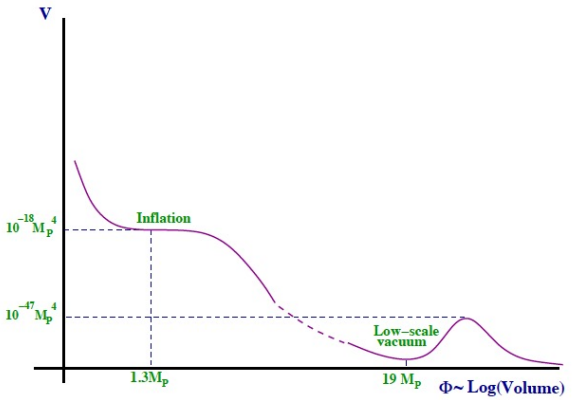
Burgess, Cicoli, FQ 2013

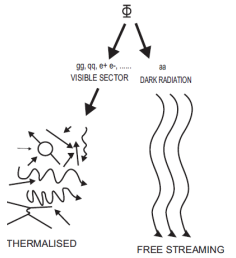
Challenges: eta problem, scales (KL problem), moduli stabilisation, observations?

e.g. After Inflation

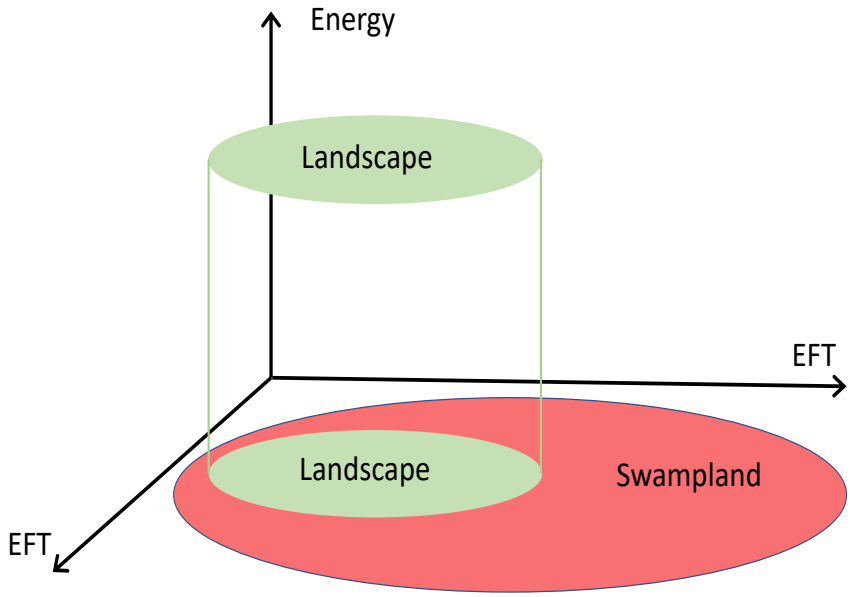




- Period of Moduli (matter) domination
- Or Kination + matter domination+radiation domination
- Oscillons or Oscillatons (boson stars)
- Reheating=moduli decay
- General constrain: dark radiation!
- Axiverse
- Potential signatures: High frequency Gravitational waves!!!

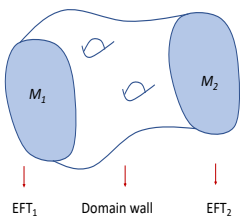


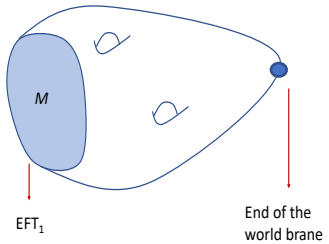
The Swampland and Cosmology ?



Swampland Conjectures and Cosmology?

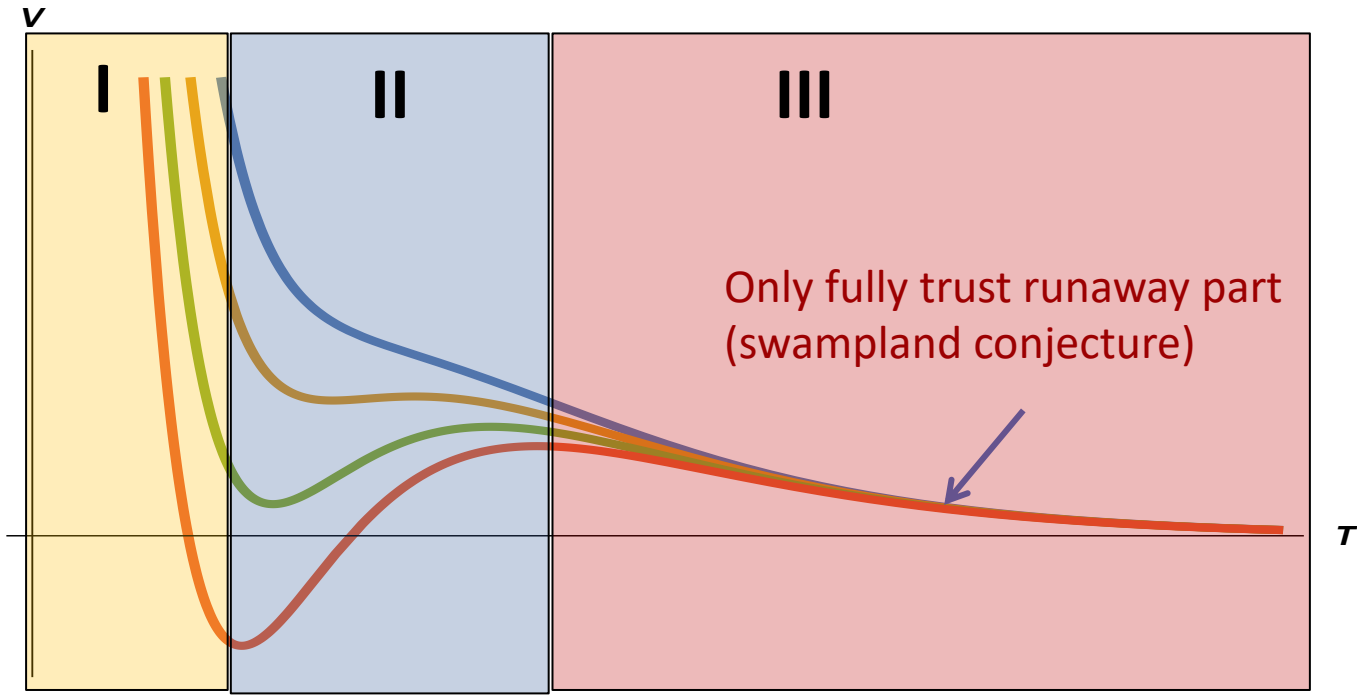
- **Distance conjecture** (constrain large field inflation,…)
- **De Sitter conjecture** (against the dS landscape, slow roll inflation,…)
- **Trans-Planckian censorship conjecture** (against sub Pnackian modes becoming macroscopic)
- **Cobordism conjecture** (generalizing absence of global symmetries to cobordism with potential cosmological implications)





dS=Dine-Seiberg

Dine, Seiberg 1985

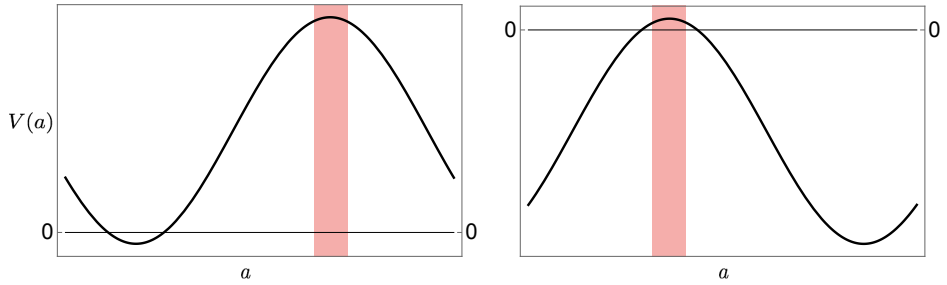


$V \longrightarrow 0$ at weak coupling and large volume.

Region II is not under full control but the most interesting phenomenologically to get hierarchies e.g. introduction of fluxes, large N, curvatures,….

De Sitter vs Quintessence

- If dS conjecture is valid alternative quintessence (slow-roll scalar)
- Quintessence need: All moduli stabilized except for one that rolls.
- Quintessence ≠ Runaway!!!
- String scalars roll too fast. Best quintessence candidate: hilltop axion but much fine-tunning…



Cicoli et al 2018,
Cicoli et al 2021
Hebecker et al 2021

Some Questions to Swamplanders

Is there anything new to say about:

- The wave function of the universe?
- Vacuum transitions?
- New model of inflation?
- Select preferred class among the known inflation proposals?
- Reheating?
- Same question for alternatives to inflation
- Alternative to the landscape to address dark energy?
- Quintessence?
- Dark matter candidates in general ?
- Dark radiation?
- The Standard Model (selection mechanism among existing constructions)?...