String theory and experiment: a new hope

Nissan Itzhaki, PASCOS 2025

Based on WIP with Uri Peleg and Paul Steinhardt

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String theory will never make

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Light strings look like particles.

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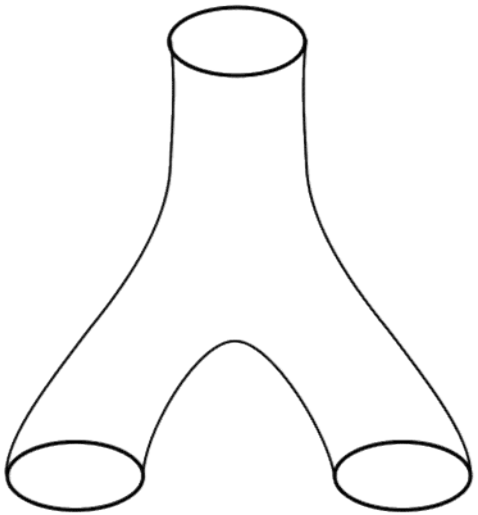

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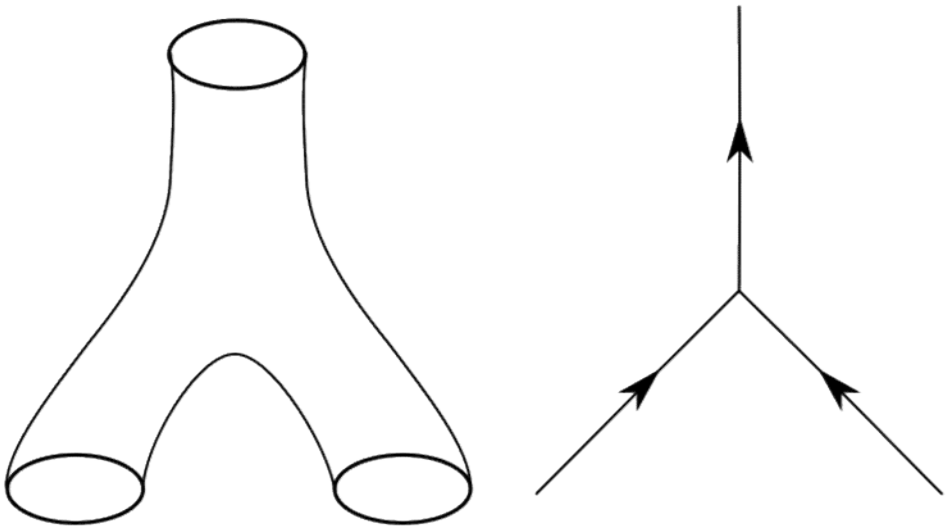

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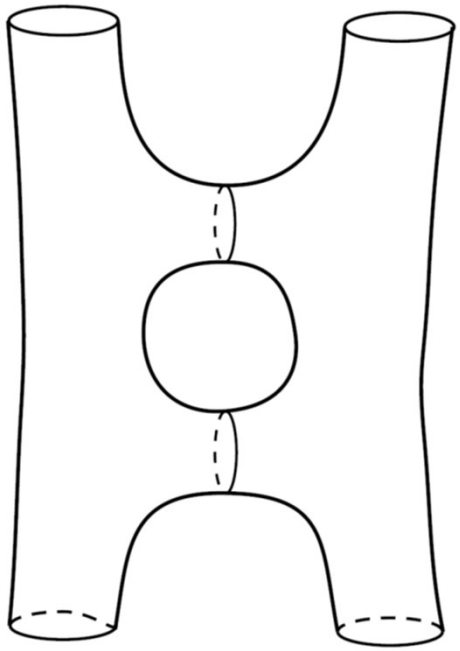

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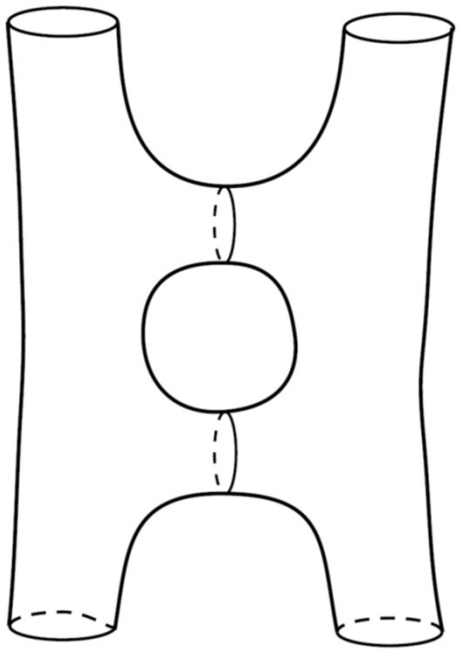

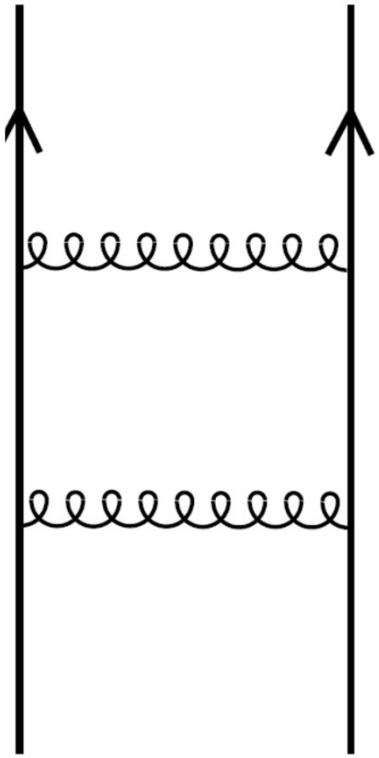

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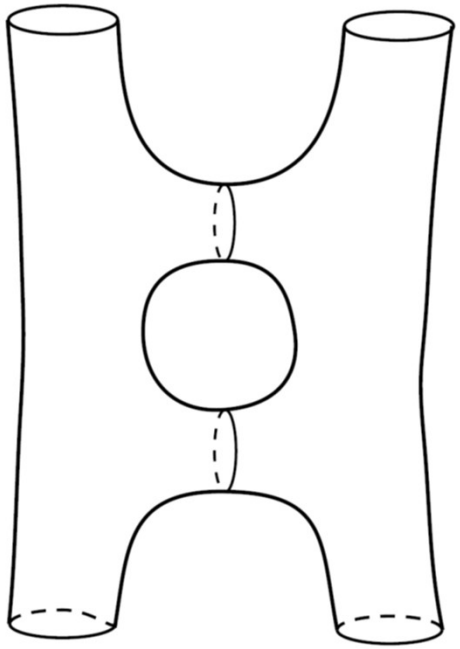

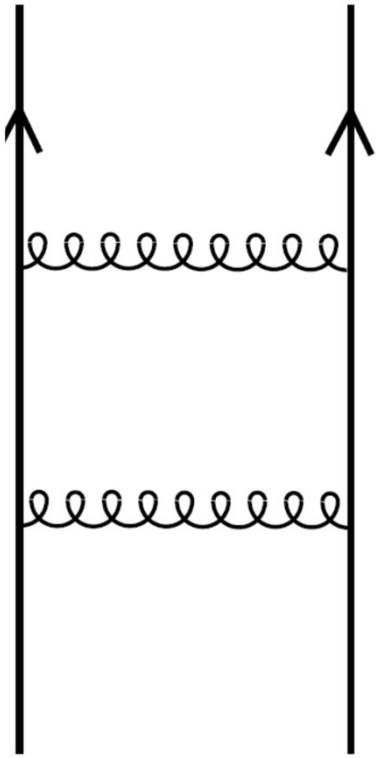

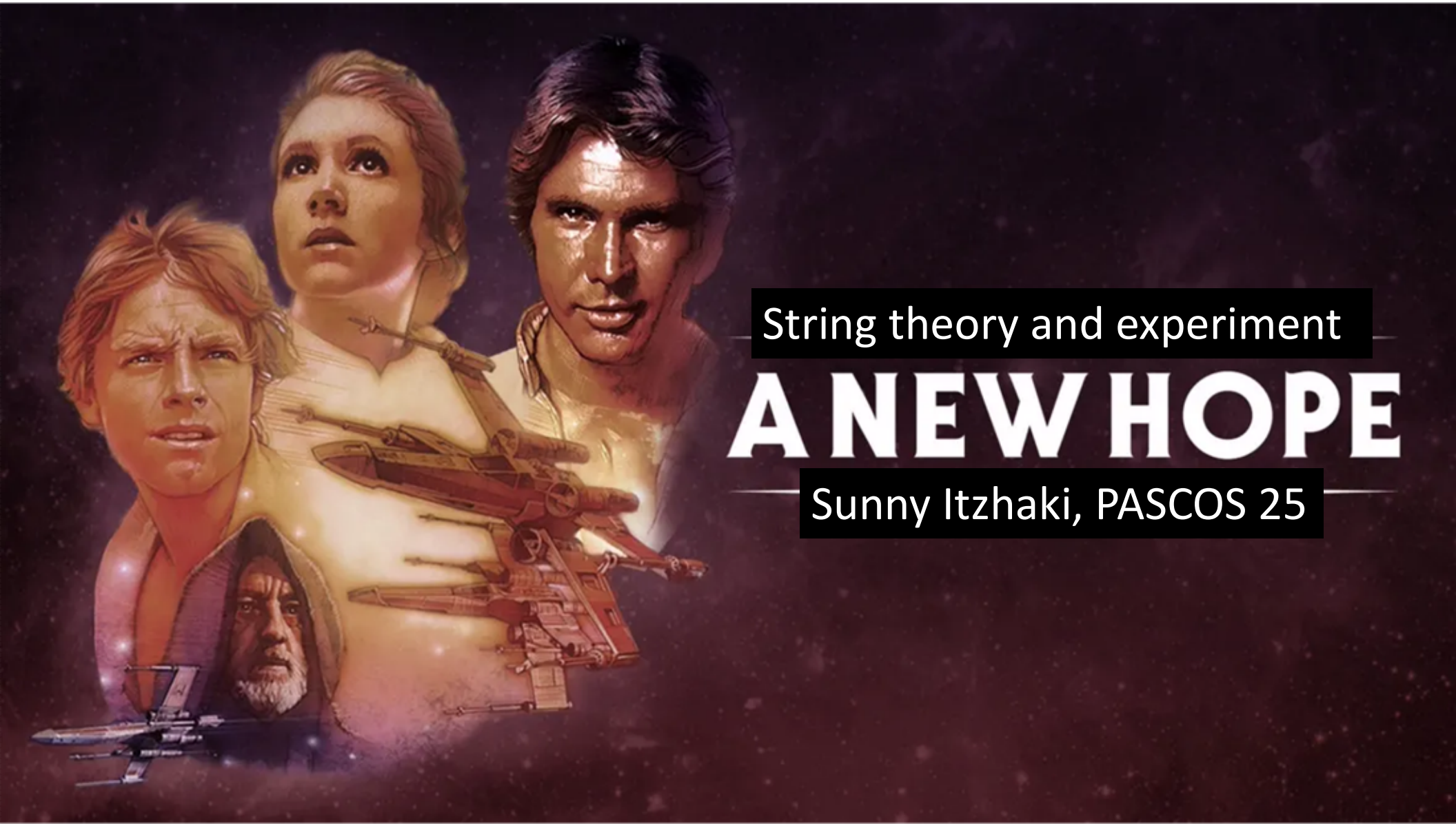
String theory and experiment
A NEW HOPE
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Main claim

In dynamical situations:

There are light strings that do not look like particles

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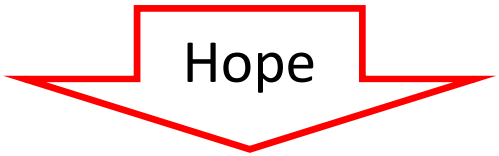

Unique stringy imprints

Plan:

1- Describe these strings.

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2- Their possible implications to cosmology

(WIP with Uri Peleg and Paul Steinhardt).

Consider the simplest time dependent background in string theory:

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a time like linear dilaton

$$ds^2 = -dt^2 + dx^2 + \ldots, \qquad \boxed{\Phi = Qt}$$

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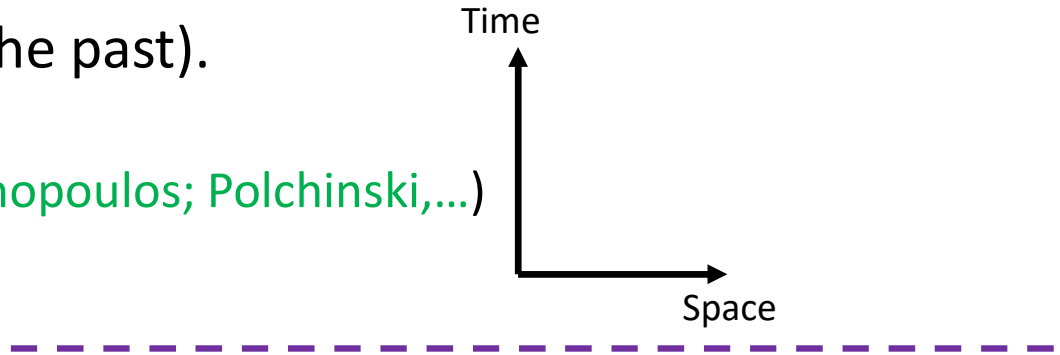
Since the late 80's people considered this with Q<0 as a toy model for

the big-bang (singularity in the past).

(Antoniadis, Bachas, Ellis and Nanopoulos; Polchinski,…)



Consider a time like linear dilaton

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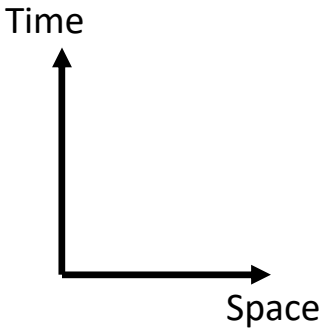
Q>0 ➡ singularity in the future



Consider a time like linear dilaton

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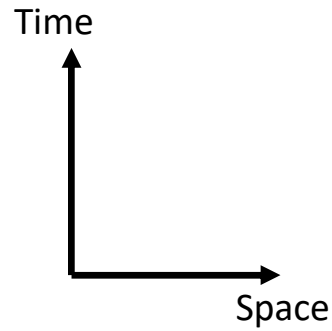
Q>0 ➡ singularity in the future

Strings have to satisfy the Virasoro constraints:

$$-(\partial_{\pm} t)^2 + (\partial_{\pm} x)^2 + \ldots + \alpha' Q \partial_{\pm}^2 t = 0$$



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sub leading yet linear

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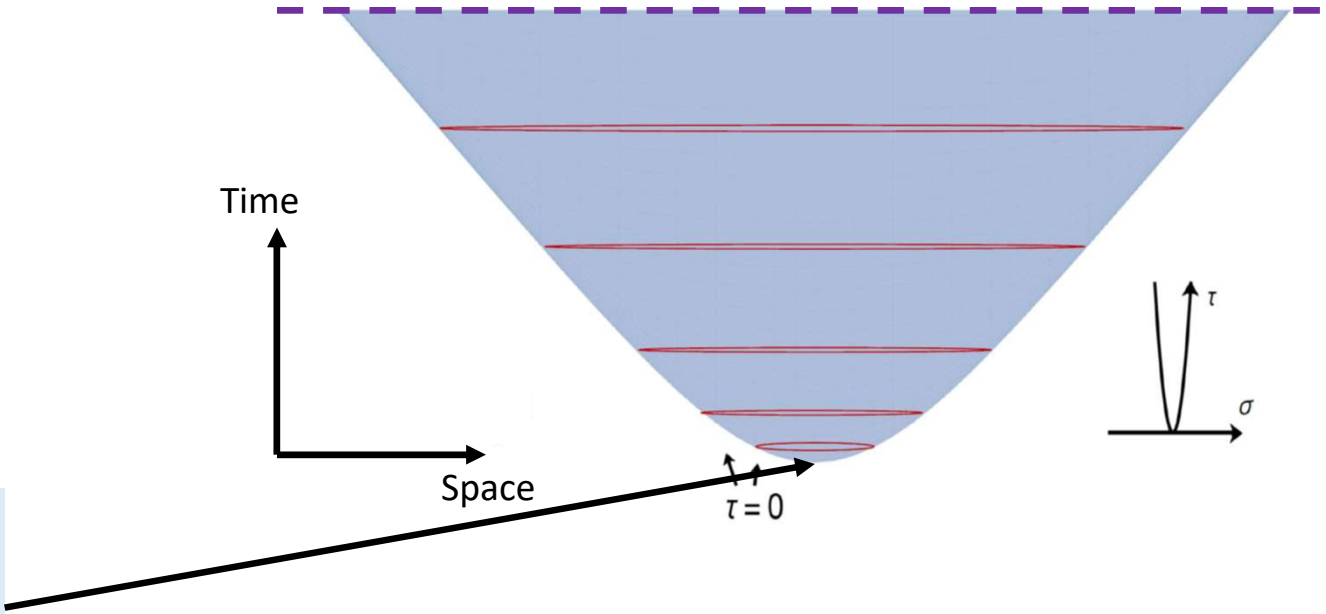
sub leading yet linear

Leads to new solutions that are

simply absent when Q=0 !!!

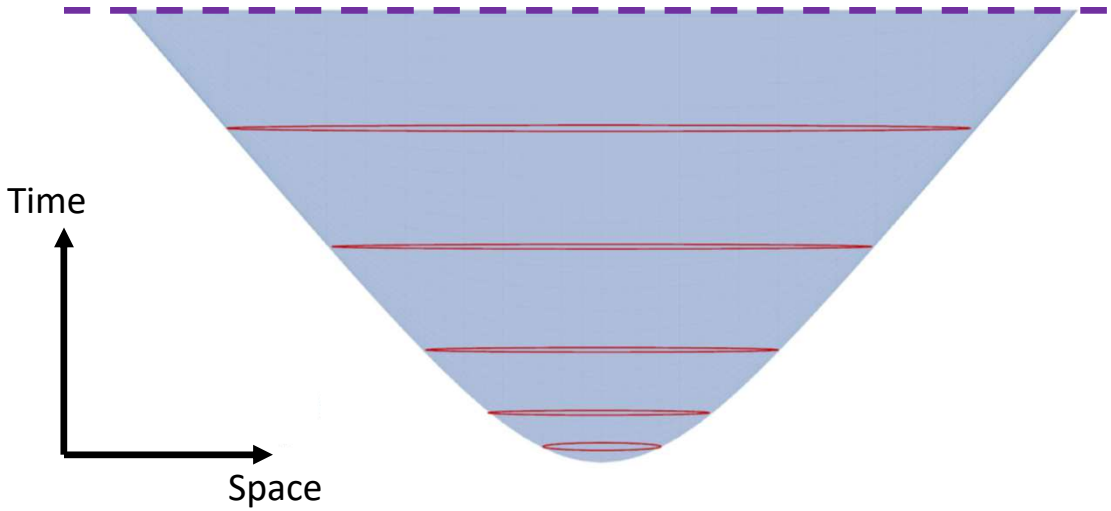
$$t(\tau,\sigma) = t_0 + \alpha' Q \log\left(\frac{1}{2}\cosh\left(\frac{\tau}{\alpha' Q}\right) + \frac{1}{2}\cosh\left(\frac{\sigma}{\alpha' Q}\right)\right)$$



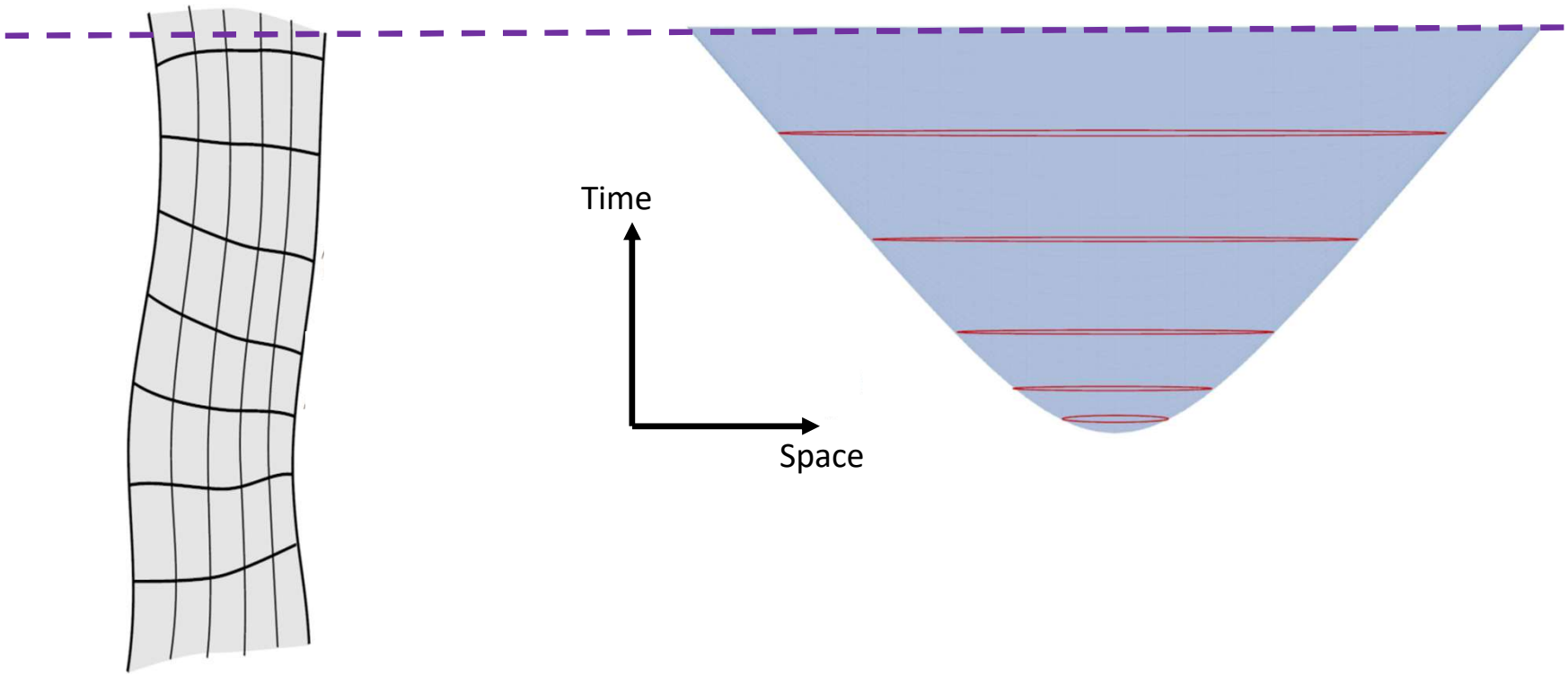
A folded string is

classically created at

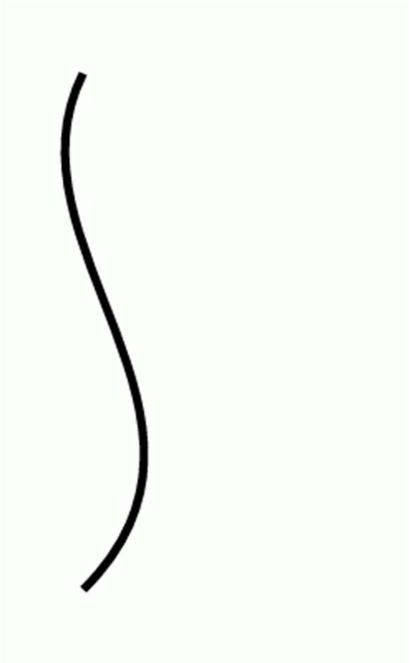
An Instant Folded Strings (IFS), does not look like a particle.

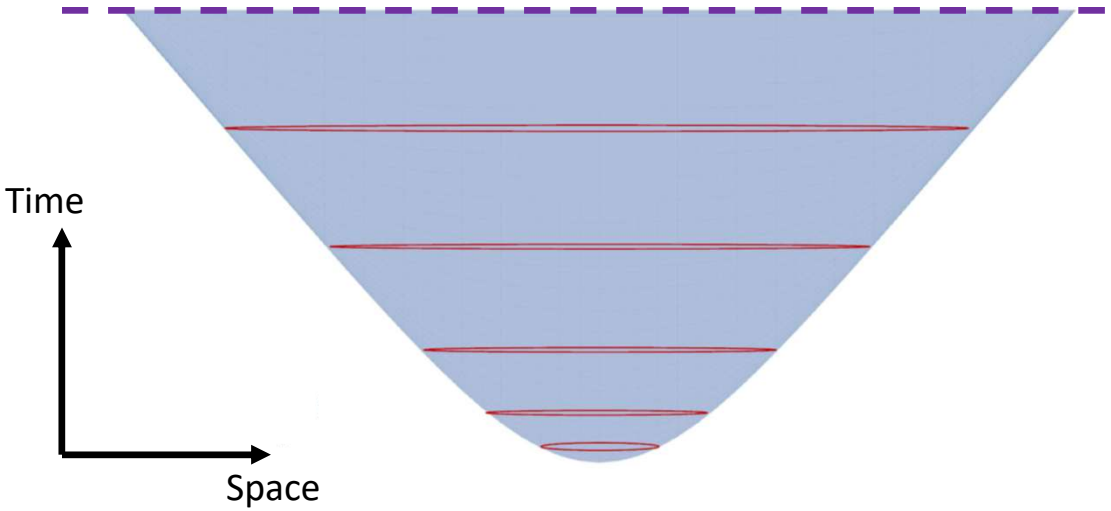


An Instant Folded Strings (IFS), does not look like a particle.

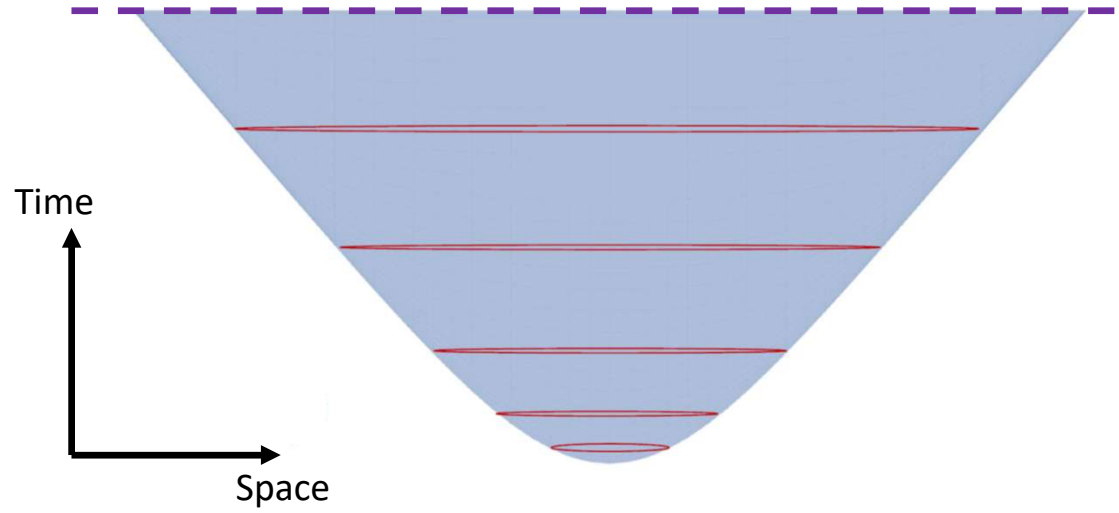


An Instant Folded Strings (IFS), does not look like a particle, even from afar





- Even from afar an IFS does not look like a particle.
- The solution is triggered by the background, but does NOT feed from the background → Total energy vanishes



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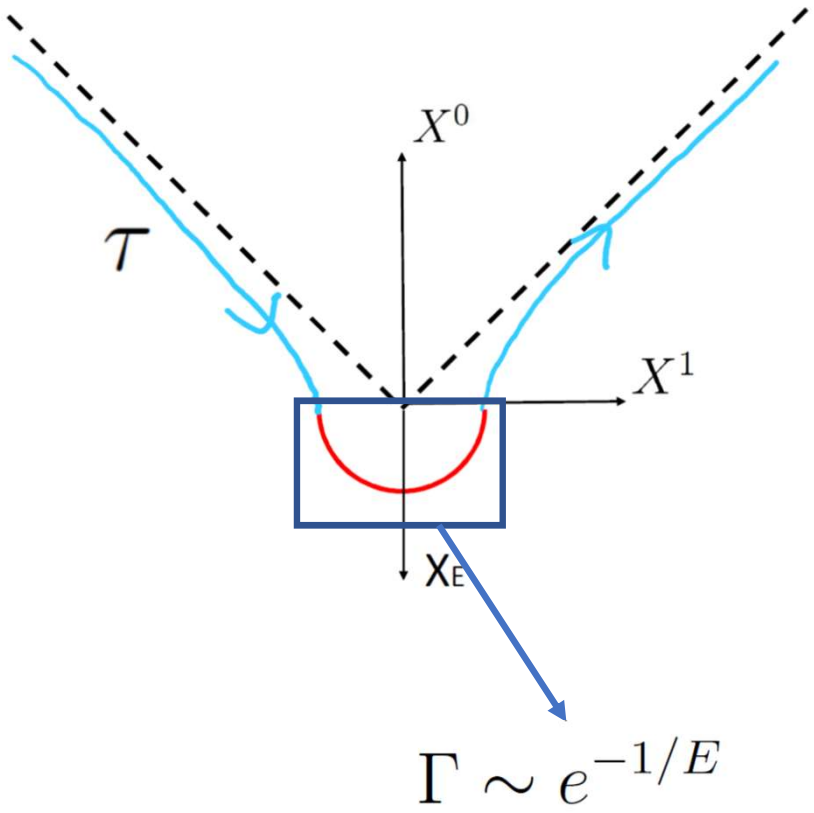
Comparison to the Schwinger effect:



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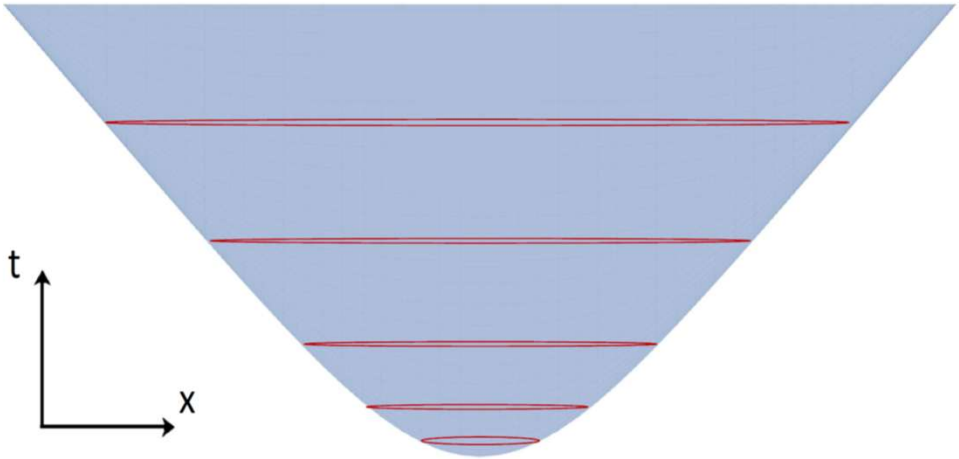

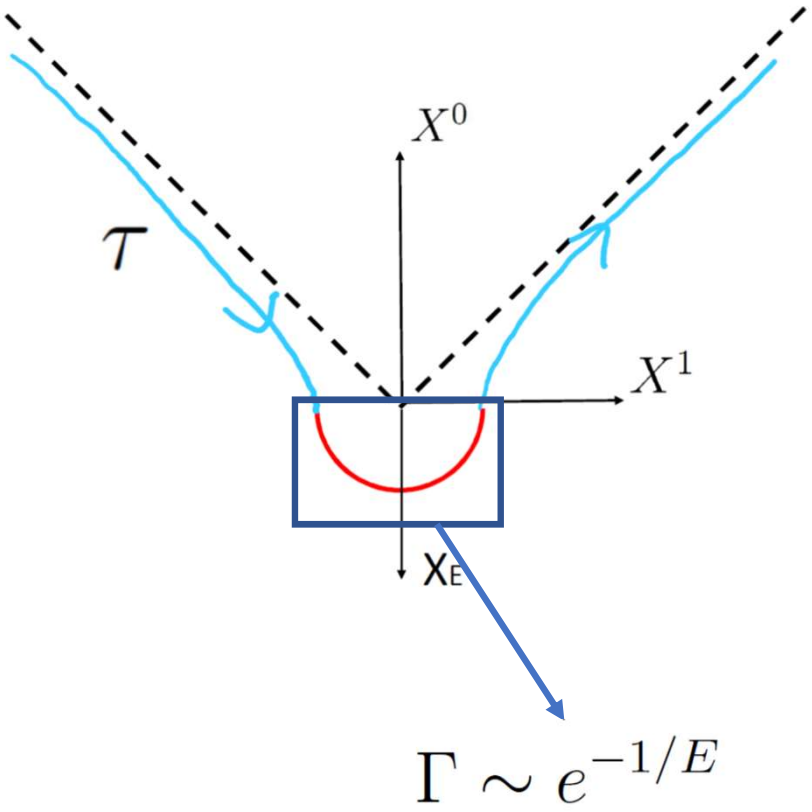

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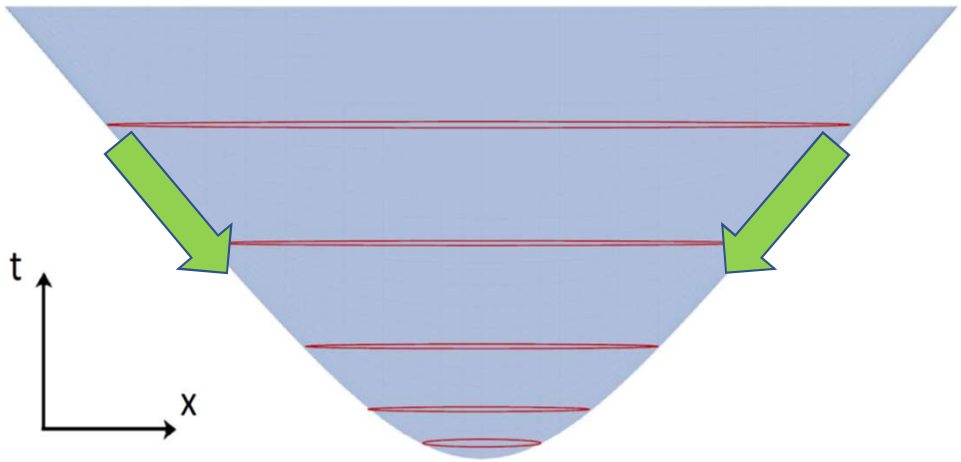
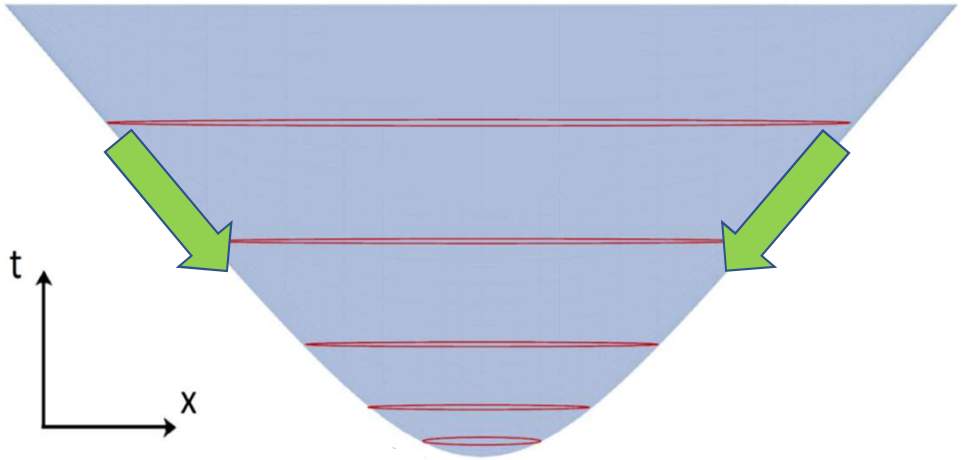


Negative energy at the fold.

An IFS is triggered by the background, but does NOT feed from the background.

At all times its total energy vanishes.



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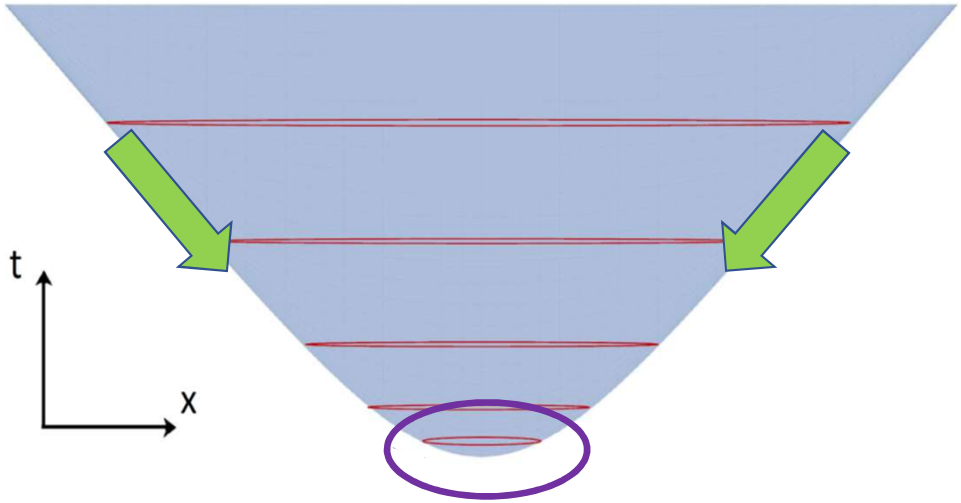

The creation scale is small

Negative energy at the fold.

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Whenever the dilaton gradient points to the future

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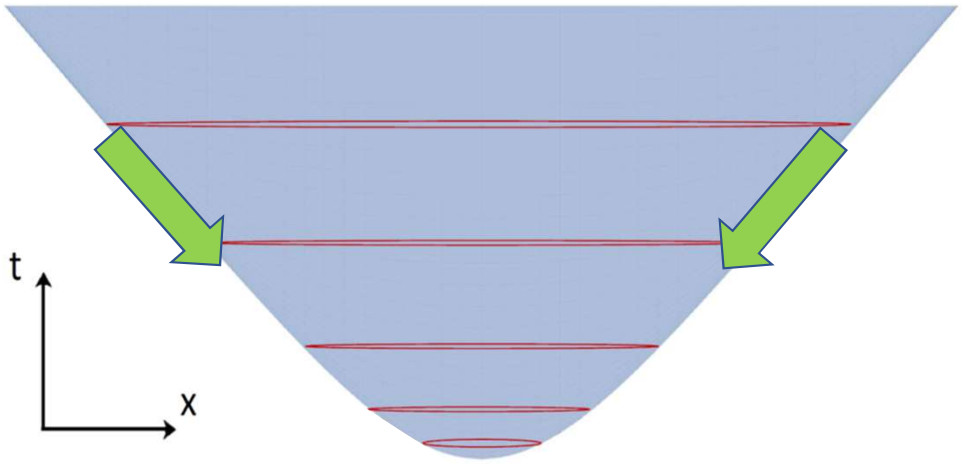
NEC is violated.

+

Can affect the IR



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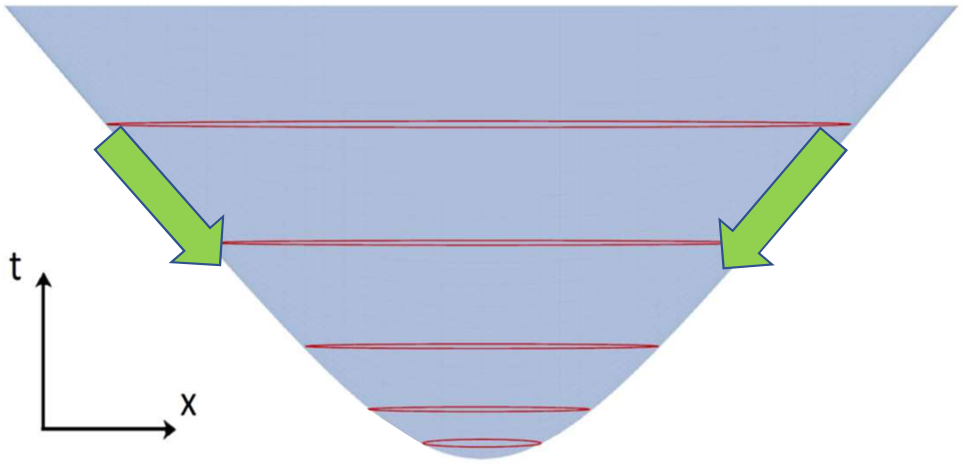
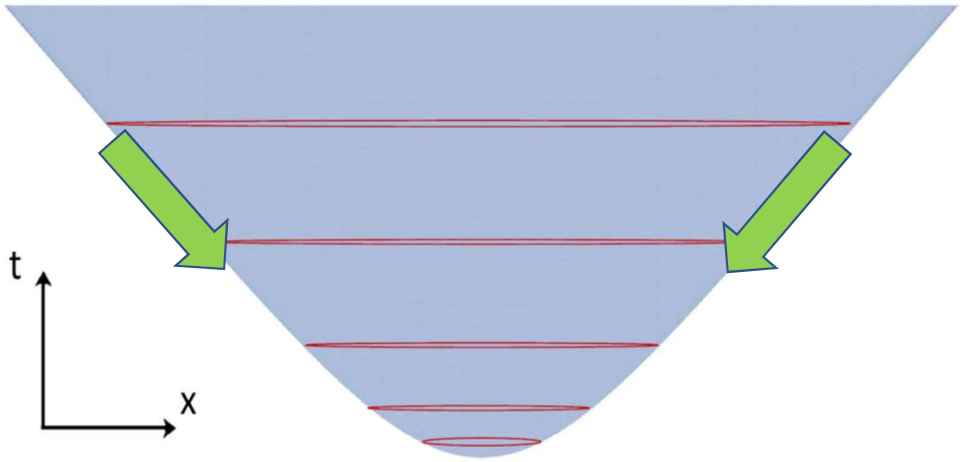
Should be fun



Cosmology (with Uri Peleg)

Cosmology



The basic idea is to

integrate out the IFSs

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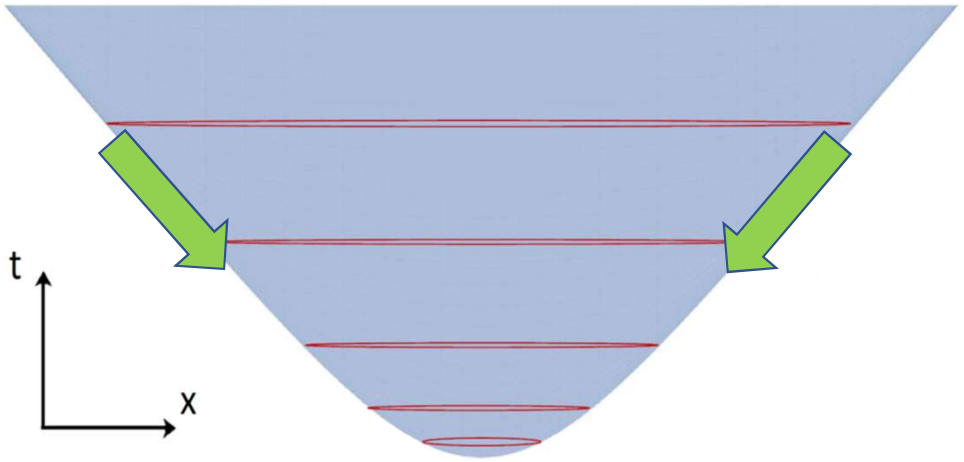

The basic idea is to

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1. Total energy=0
2. NEC is violated.

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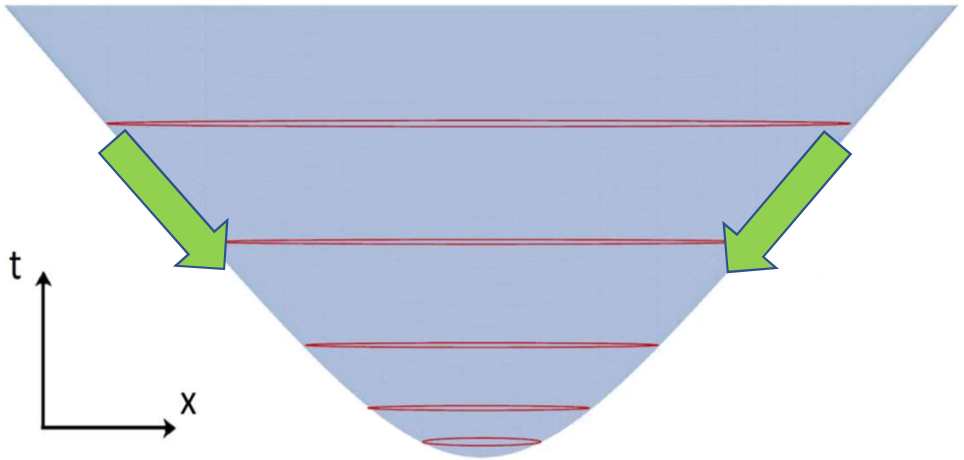

In cosmology

1. Total energy=0 → $\rho_{IFS} = 0$
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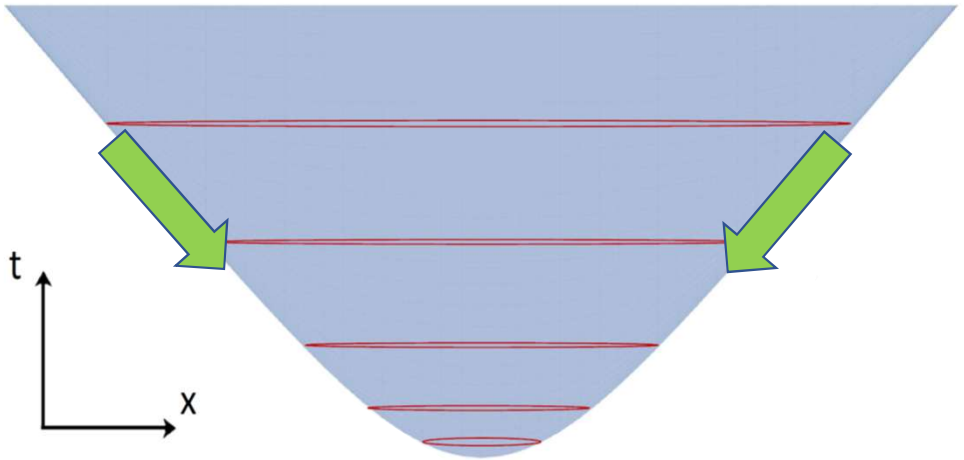
Cosmology



In cosmology

1. Total energy=0 → $\rho_{IFS} = 0$
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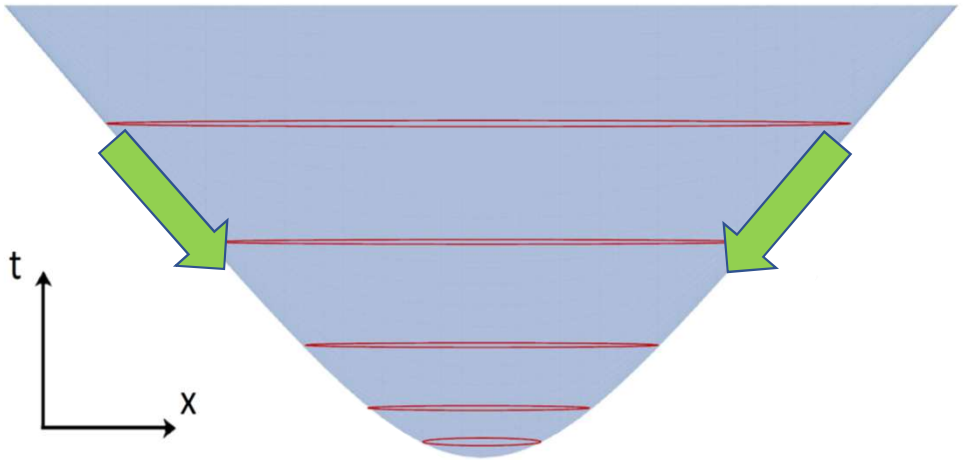

In cosmology

1. Total energy=0 → $\rho_{IFS} = 0$
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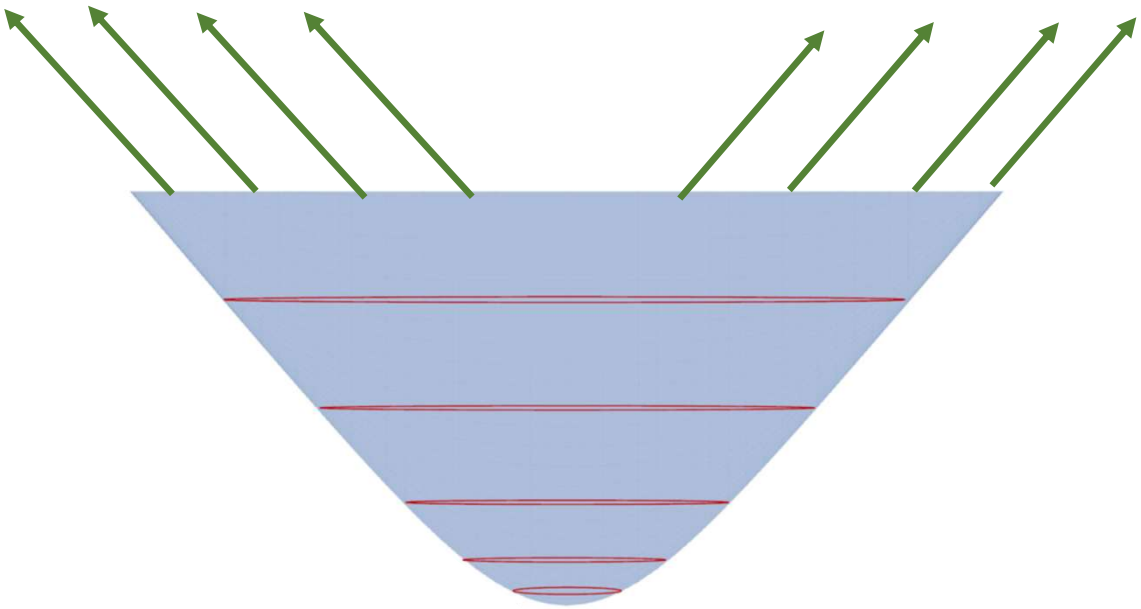
But what is it?

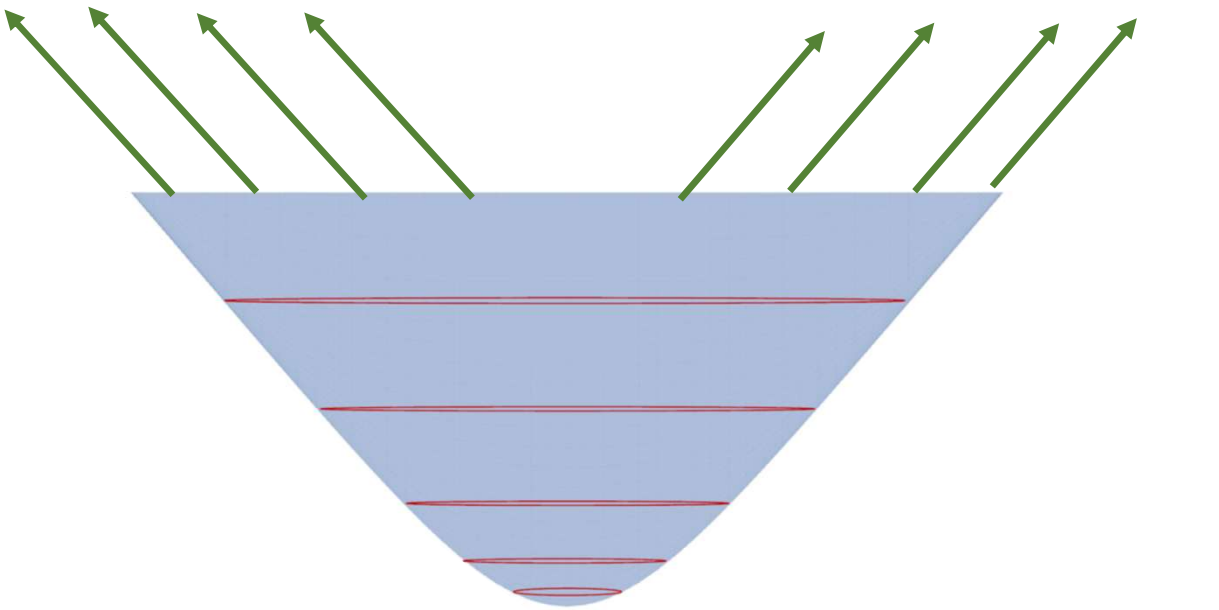
We can estimate the lifetime of an IFS to find

the effective cosmological equations of motion.



The IFS can break

$$\tau_{IFS} = \gamma \, \frac{l_s}{g_s}$$



$$\Gamma_{IFS} = \frac{\dot{\phi}^2}{128\alpha'\pi^8 g_s^2}$$

+

$$\tau_{IFS} = \gamma \frac{l_s}{g_s}$$

$$P_{IFS} \sim -\frac{\gamma^2 \dot{\phi}^2}{\alpha' g_s^4}$$

Plug $P_{IFS} \sim -\frac{\gamma^2 \dot{\phi}^2}{\alpha' g_s^4}$ into the Einstein dilaton eom

$$3H^2 = \kappa^2 \rho_{tot} \equiv \kappa^2 \left(\rho_{r-IFS} + \frac{1}{2}\dot{\phi}^2 + V(\phi) \right),$$

$$\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = -\frac{\kappa\gamma}{\sqrt{2}} \frac{\dot{\phi}^2}{g_s^2} \Theta(\dot{\phi}),$$

$$\dot{\rho}_{r-IFS} + 4H\rho_{r-IFS} = \gamma \frac{\dot{\phi}^2}{g_s^2} \left(H + \frac{\kappa}{\sqrt{2}}\dot{\phi} \right) \Theta(\dot{\phi}),$$

A cyclic universe (with Uri Peleg and Paul Steinhardt)

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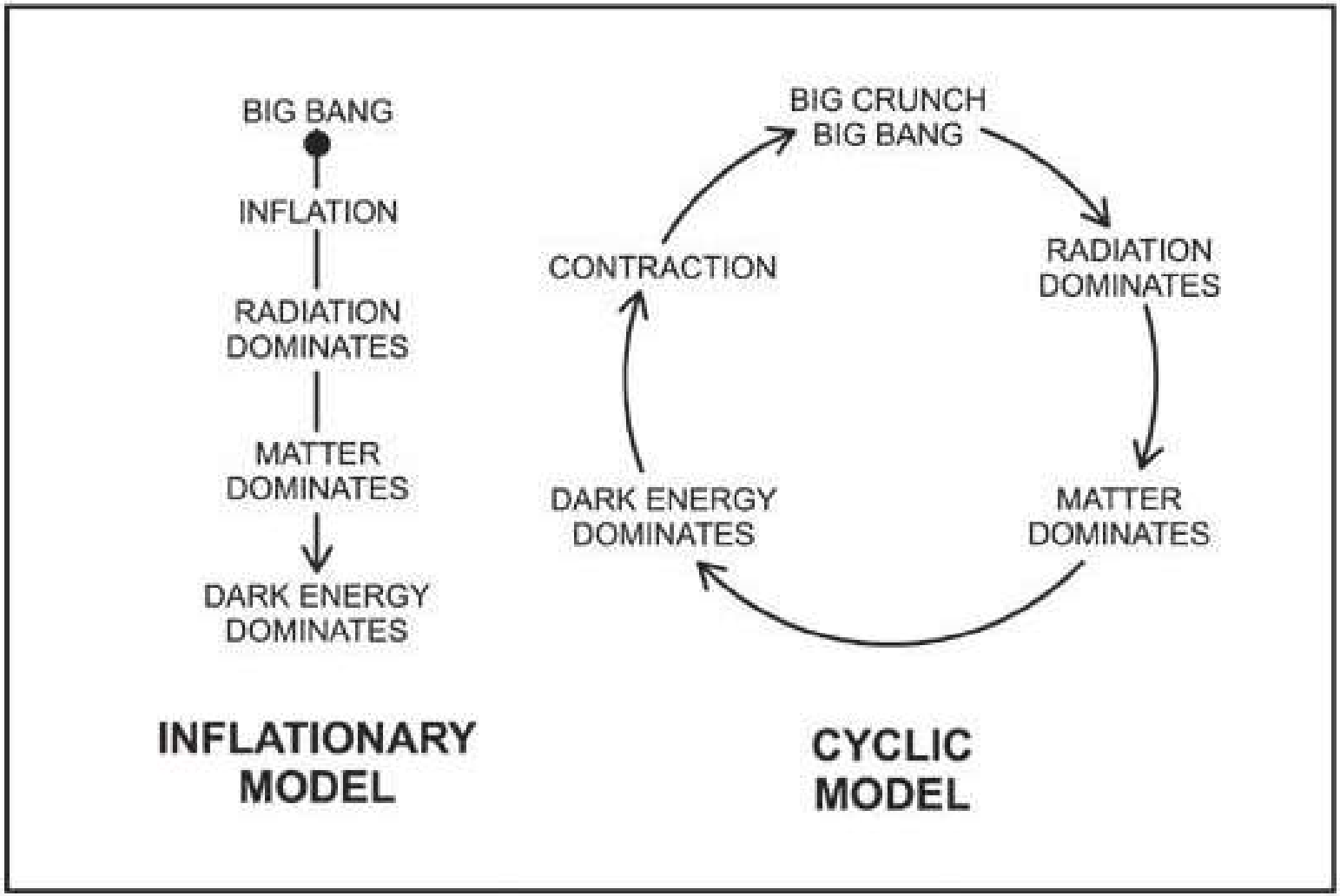
Is a model that Steinhardt and collaborators have been considering

for quite sometime as an alternative to inflation.


BIG BANG
INFLATION
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CONTRACTION
CYCLIC MODEL

Figure 01

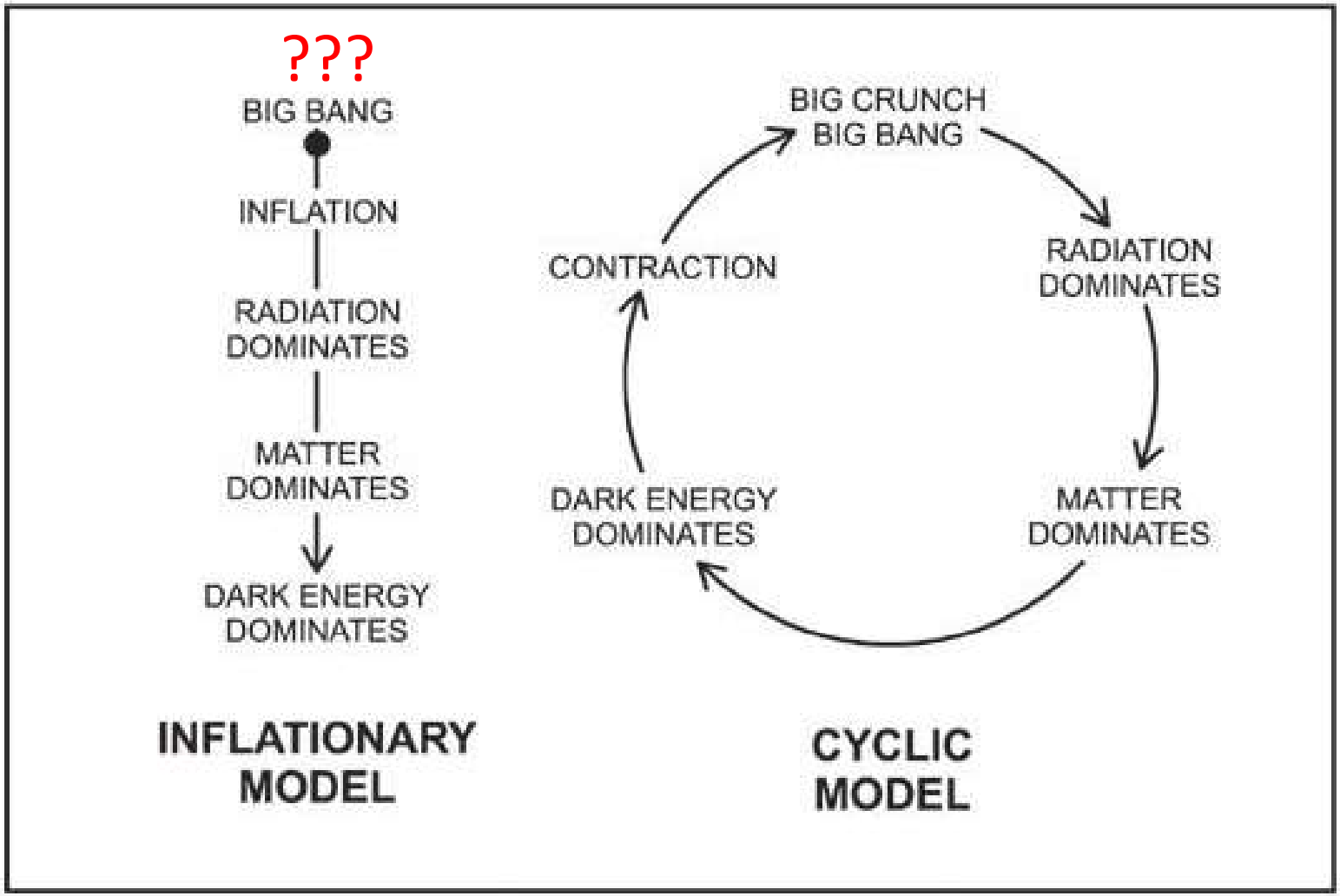
???
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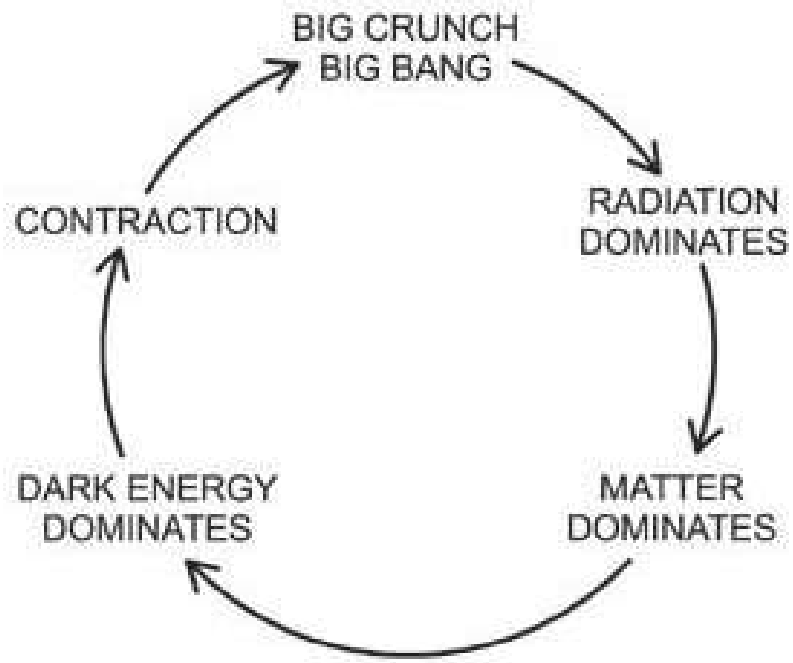
Figure 01

How to bounce?

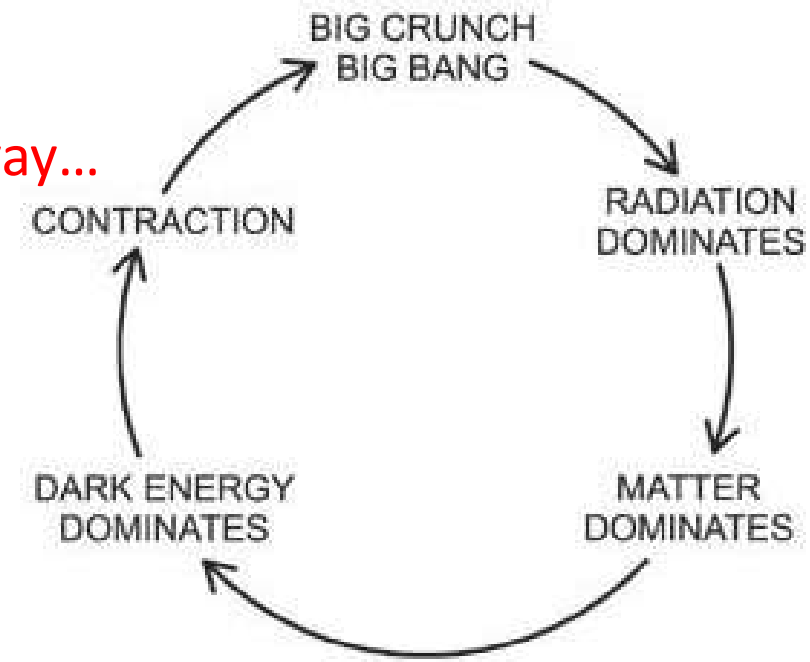


CYCLIC MODEL

Figure 01

How to bounce?

and in a controlled way…



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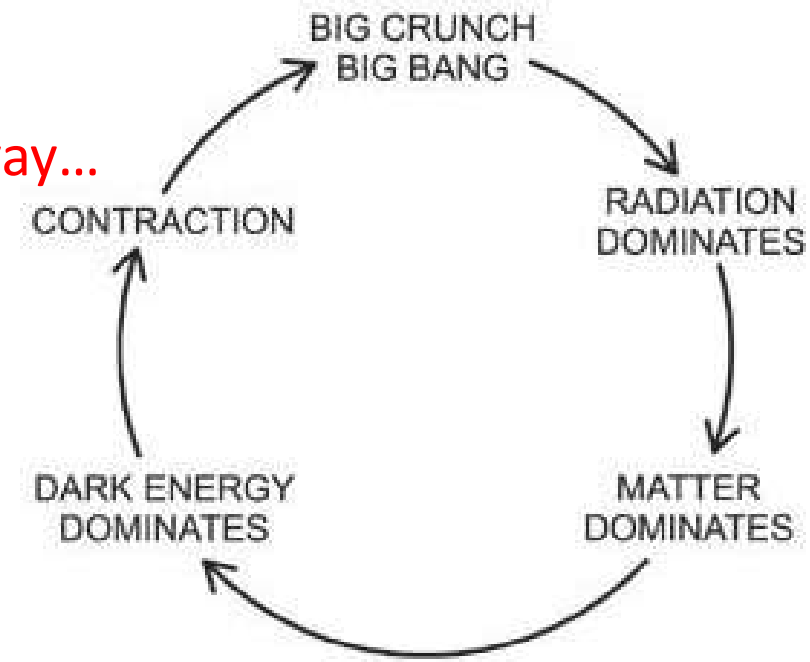


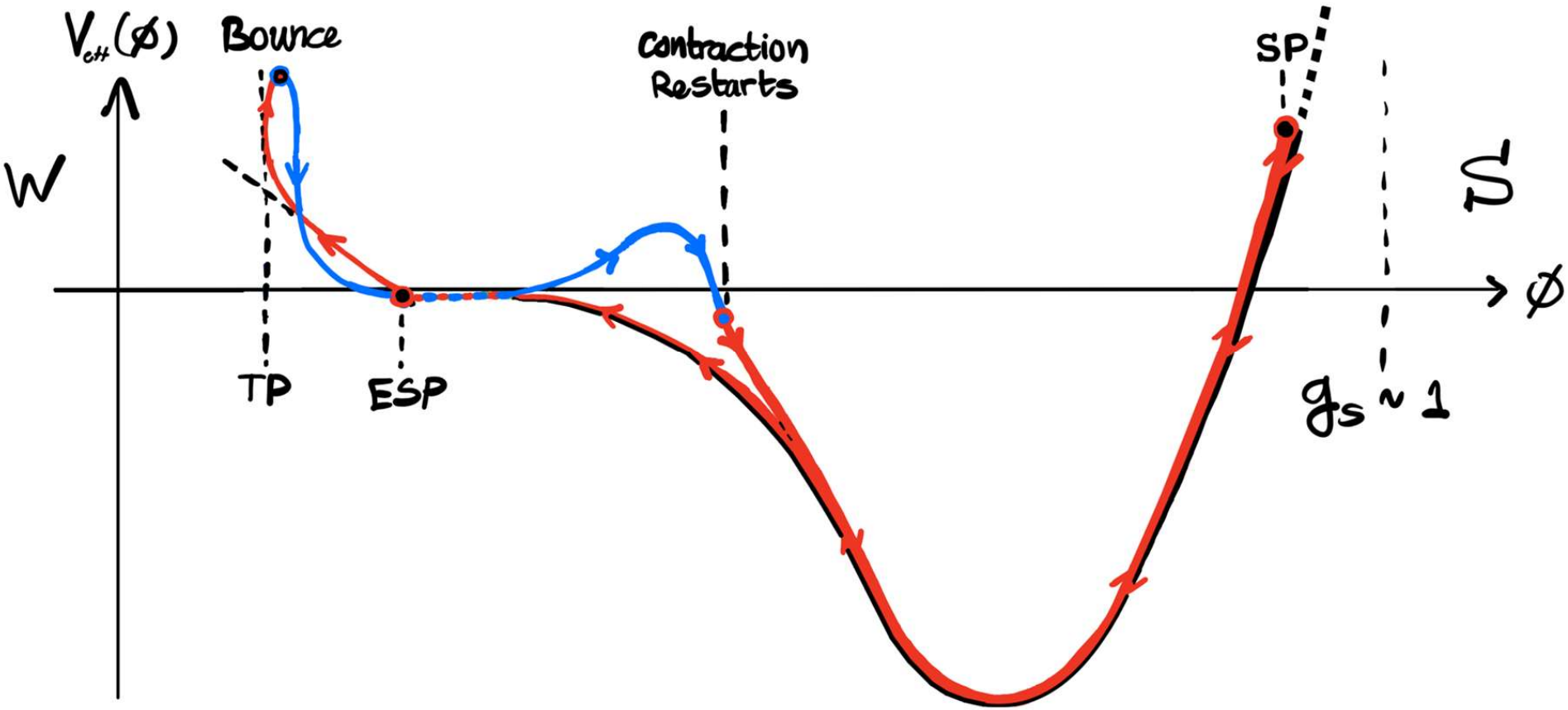
CYCLIC
MODEL

This is where IFSs

are useful.

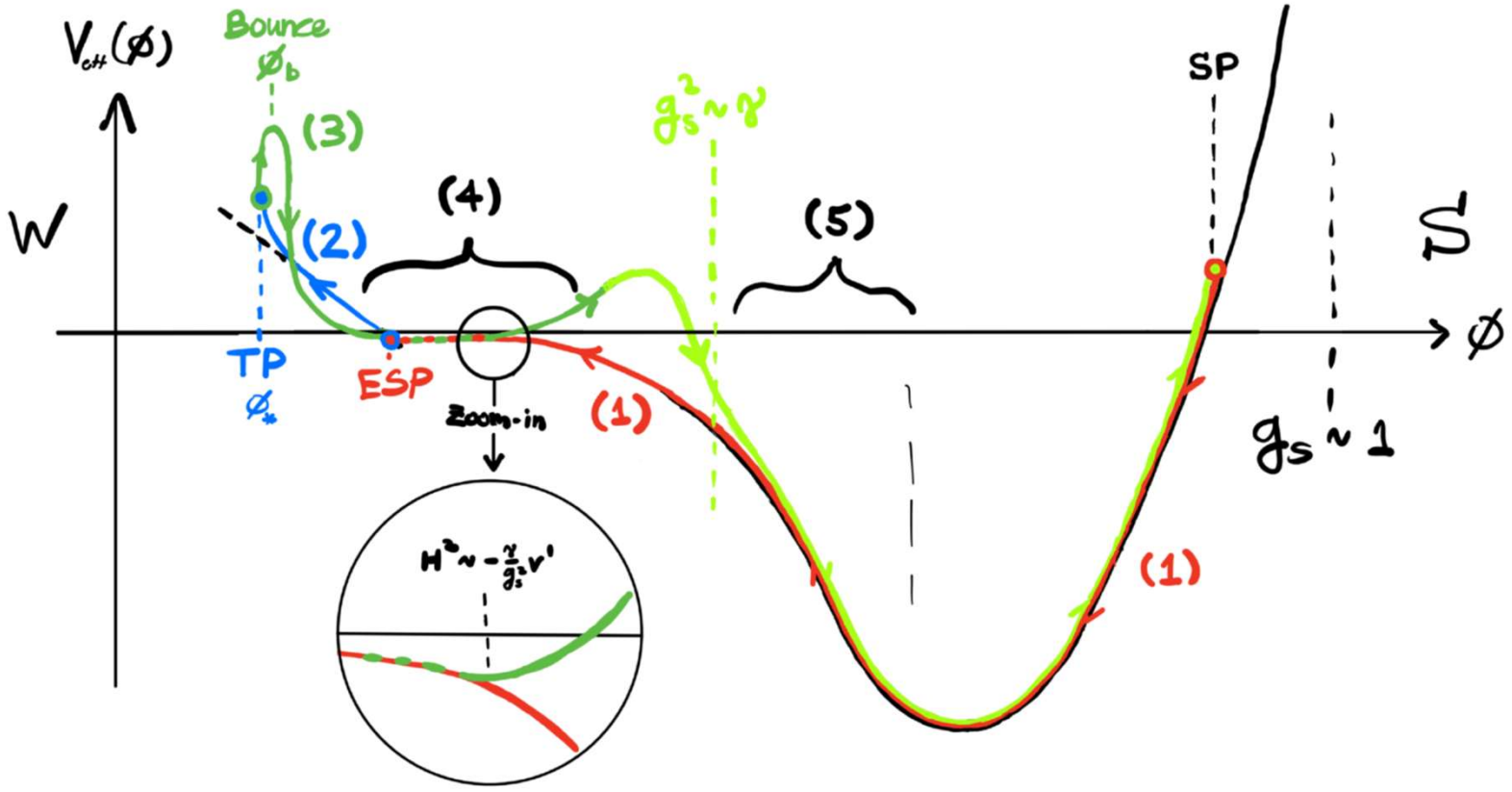
Figure 01

A cyclic universe (with Uri Peleg and Paul Steinhardt)



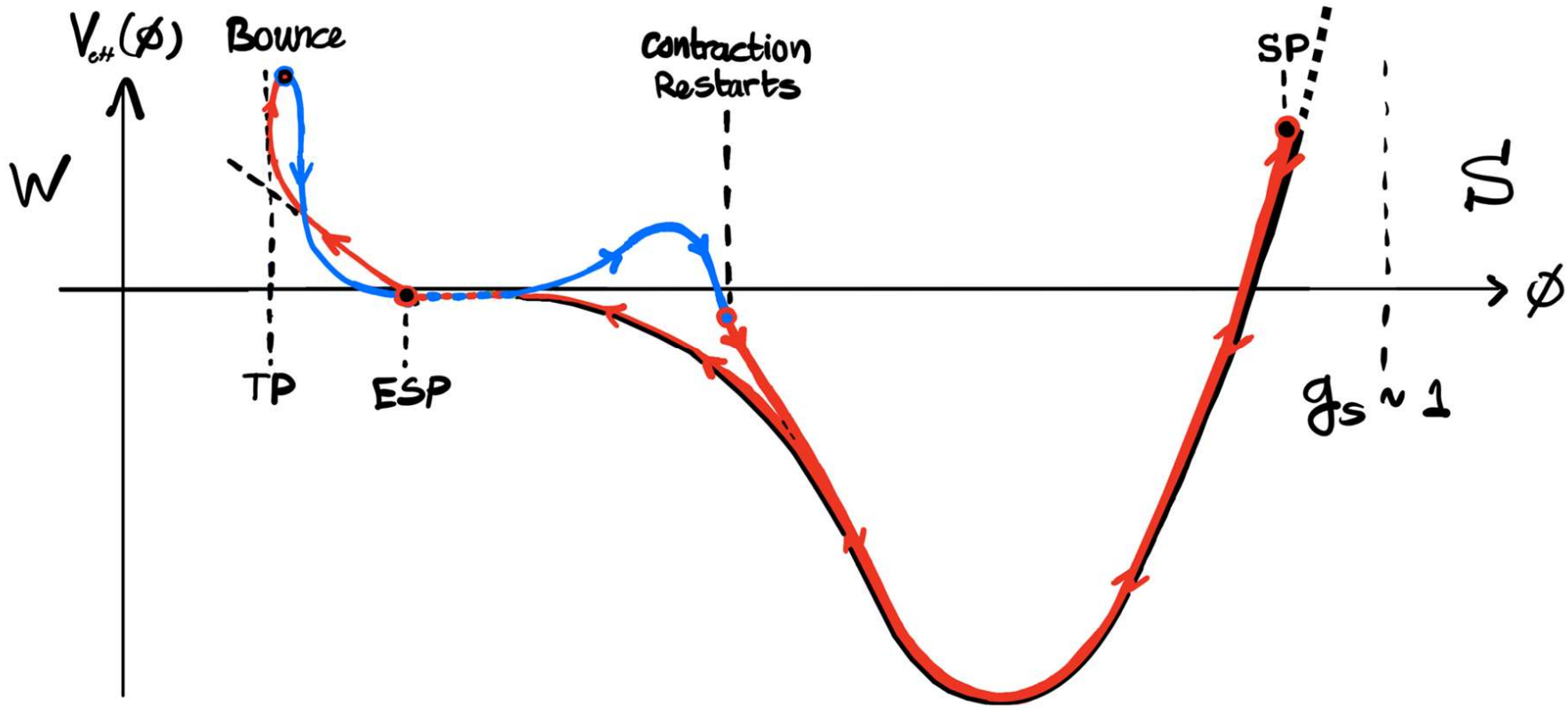
Looks complicated but uses only:

Perturbative potential, and an enhanced symmetry point (Kofman et. al).



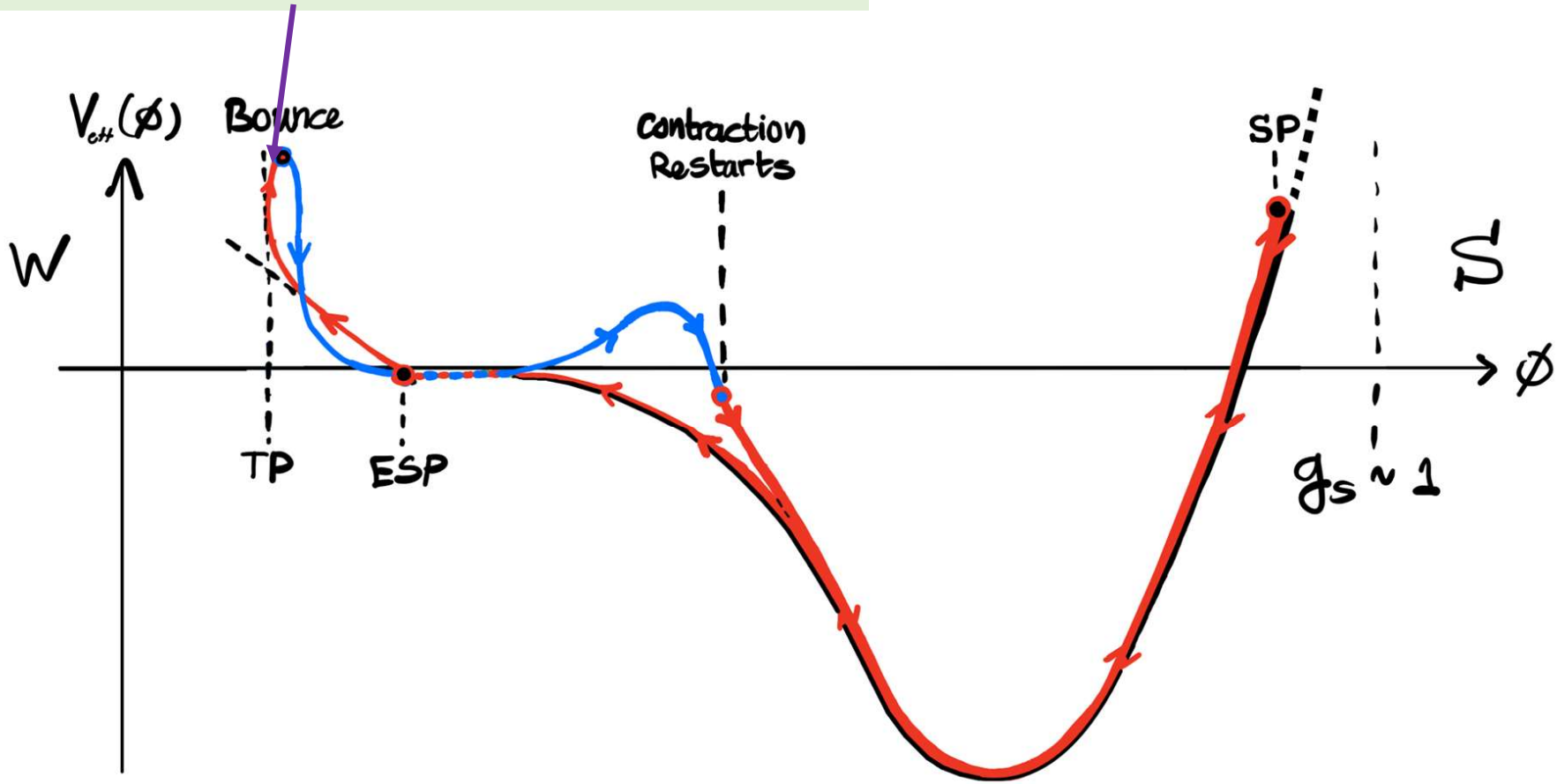
Instant folded strings play a dual role

(one expected and one unexpected):



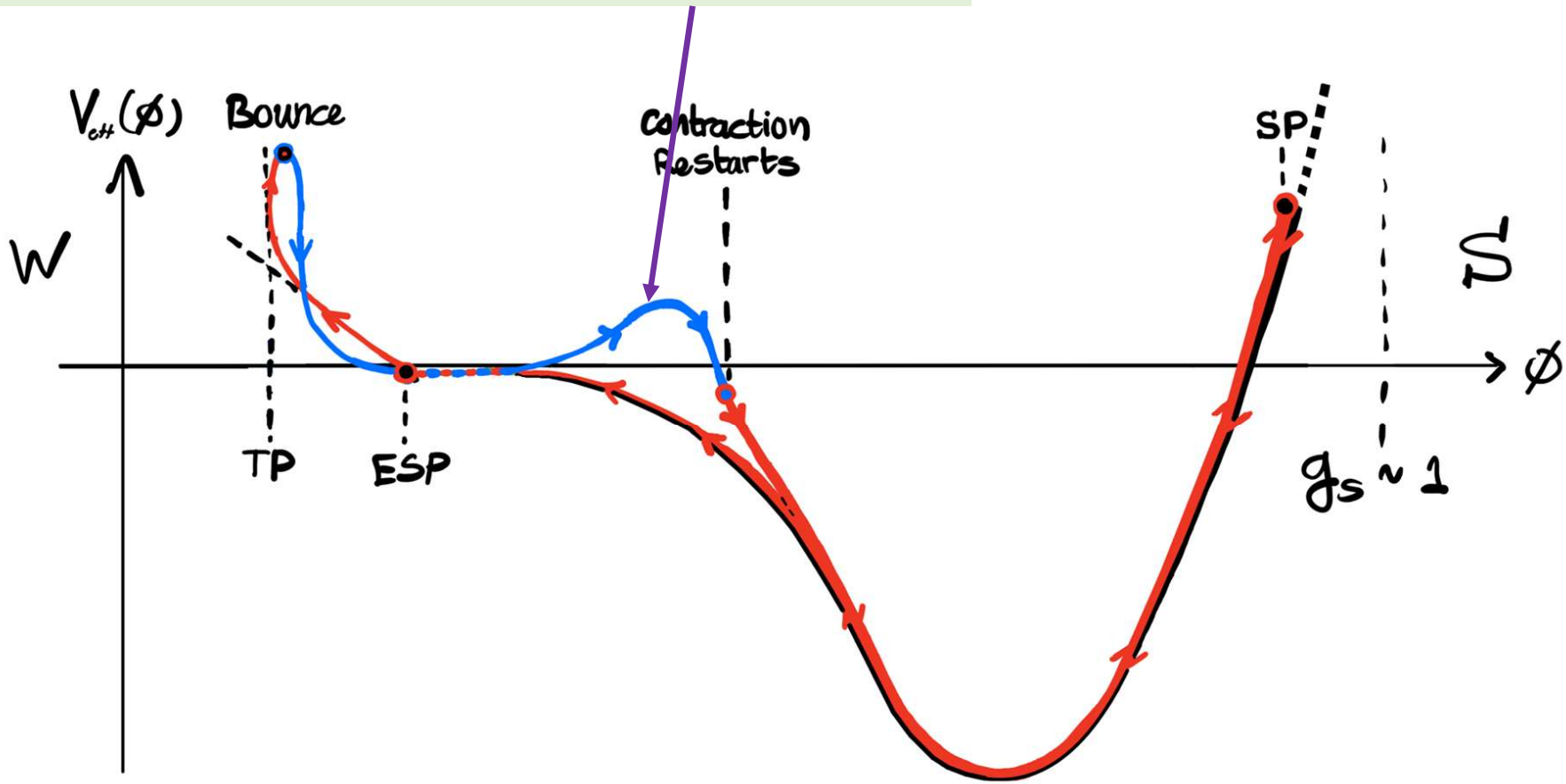
Instant folded strings play a dual role:

Expected: They mediate the bounce



Instant folded strings play a dual role:

Unexpected: they induce the dark energy



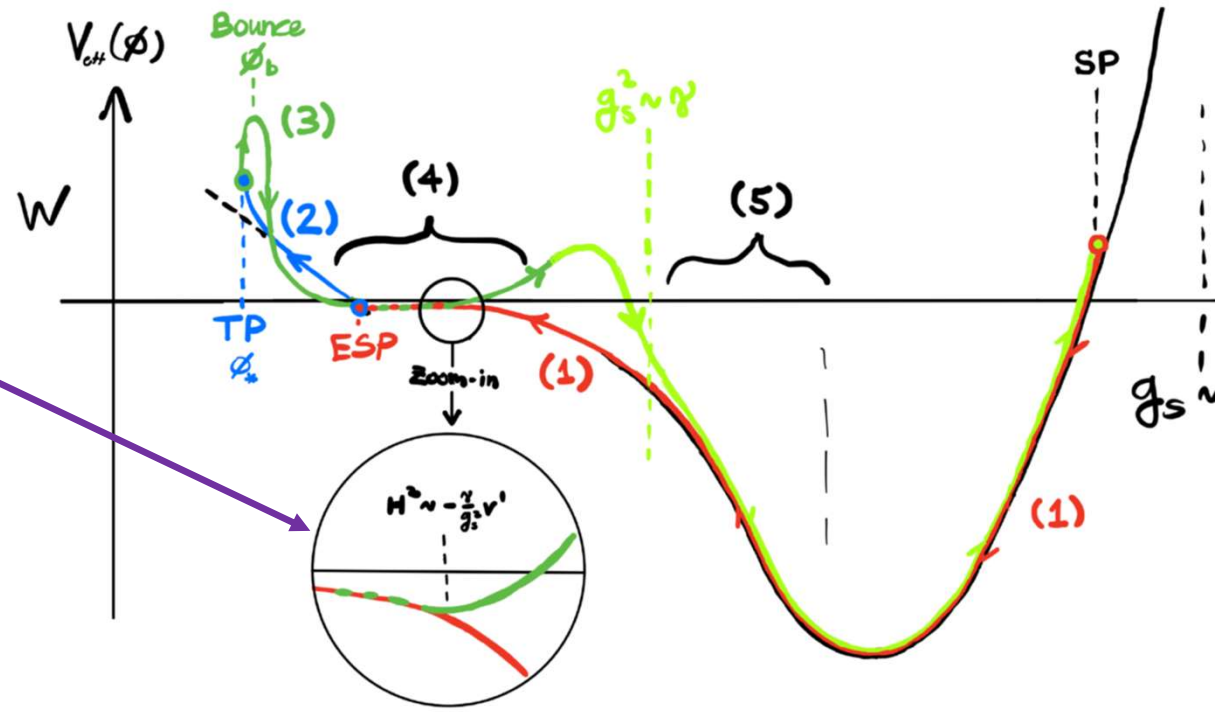
The dark energy they induce depends on V in a non standard way:

$$V_{eff} \equiv V - \frac{1}{\sqrt{8}\kappa} V'$$

The dark energy they induce is quite non standard:

It is negative until “recently”

then it goes up and down.



The dark energy they induce is quite non standard:

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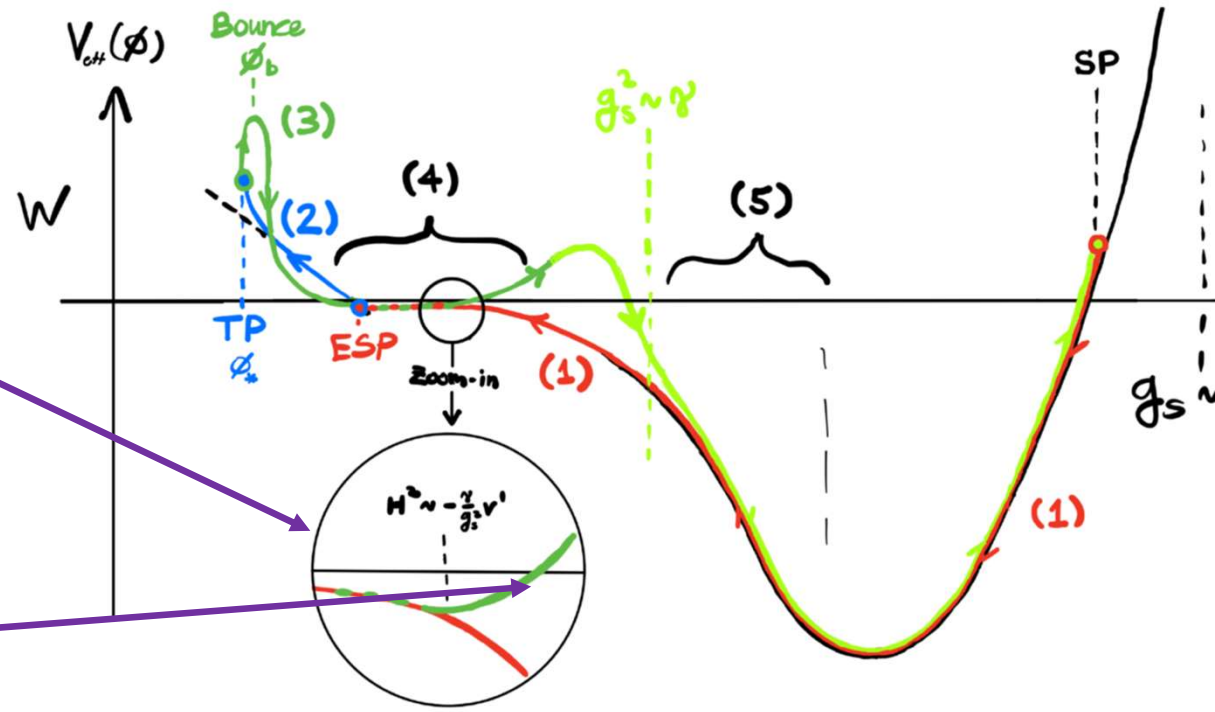

$$V_{eff} \equiv V - \frac{1}{\sqrt{8\kappa}} V'$$

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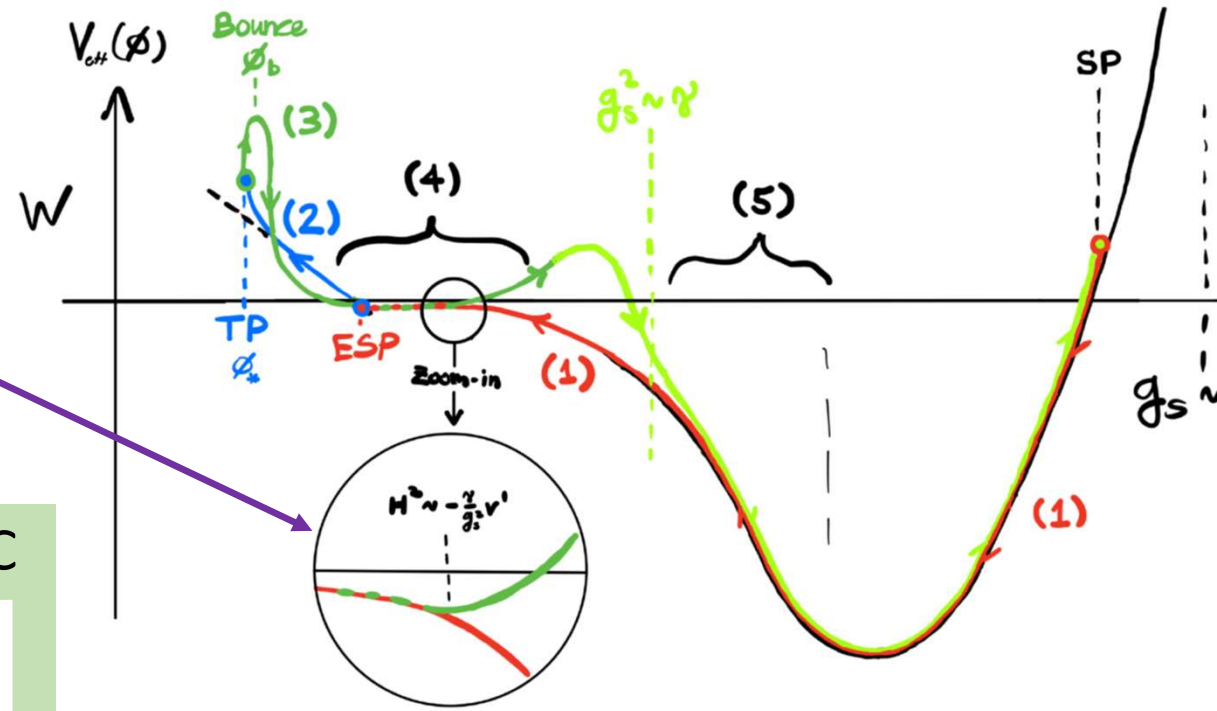

When it goes up it violates the NEC

a bit $$w = \frac{p}{\rho} = -1 - c g_s^2$$

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- Depending on the coupling to the standard model there could be many other interesting effects.

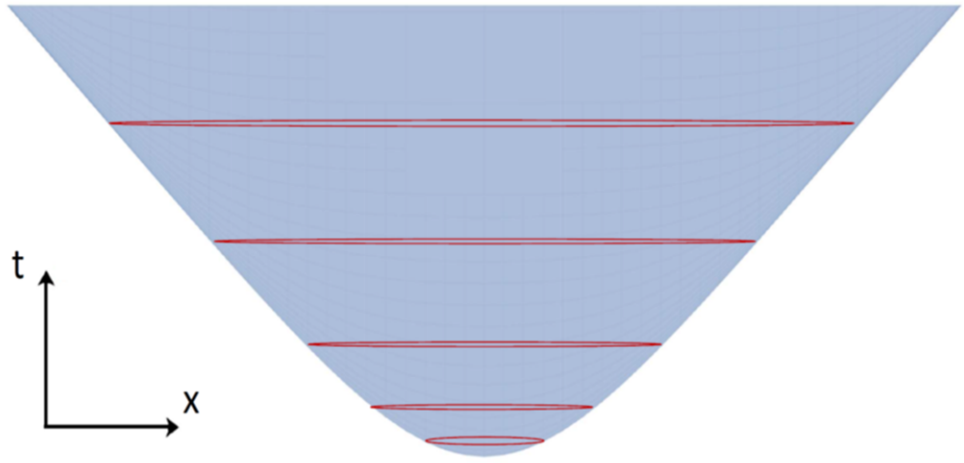
Summary:

In dynamical situations there are in fact light strings

that do not look like particles

Hope

Unique stringy imprints



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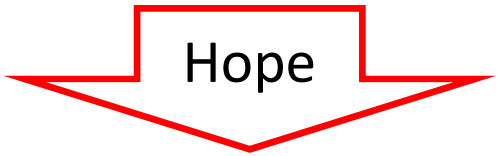

Unique stringy imprints

- With Uri Peleg and Paul Steinhardt we've started to study some aspects of the dark energy they induce.

With Uri Peleg and Paul Steinhardt we've just started to explore this.

Much work to be done

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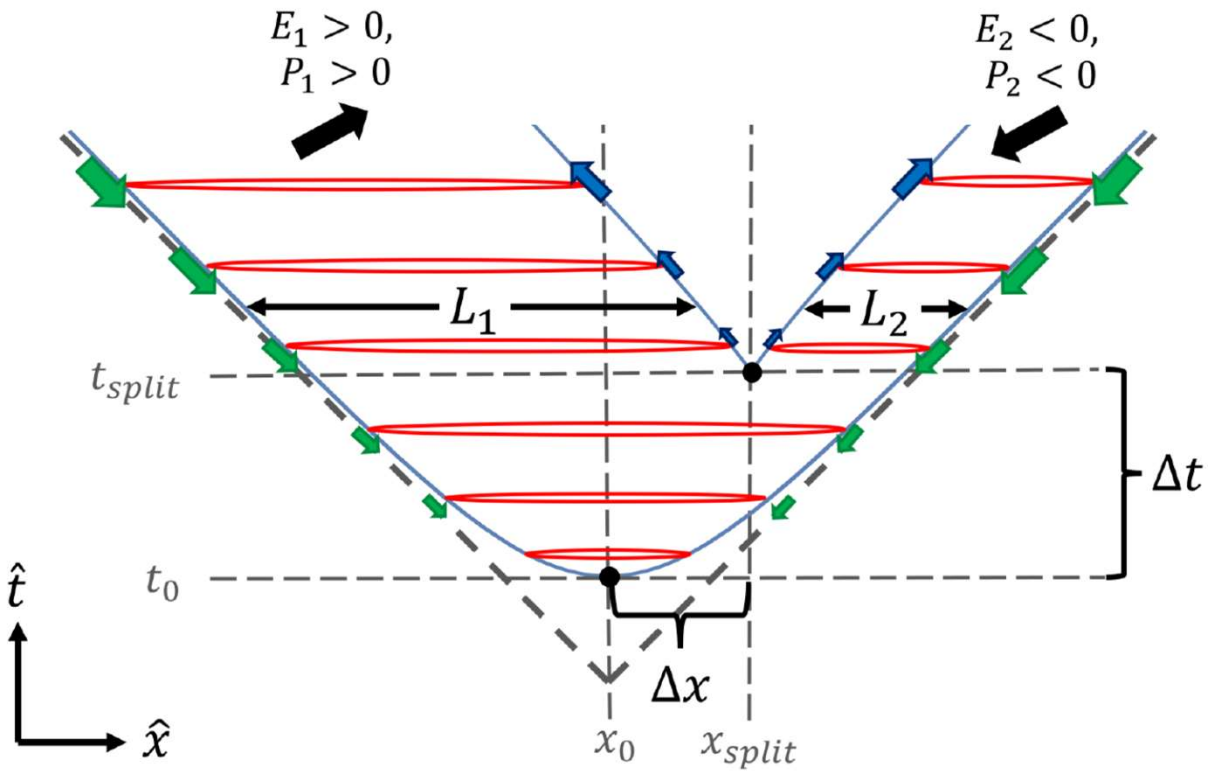

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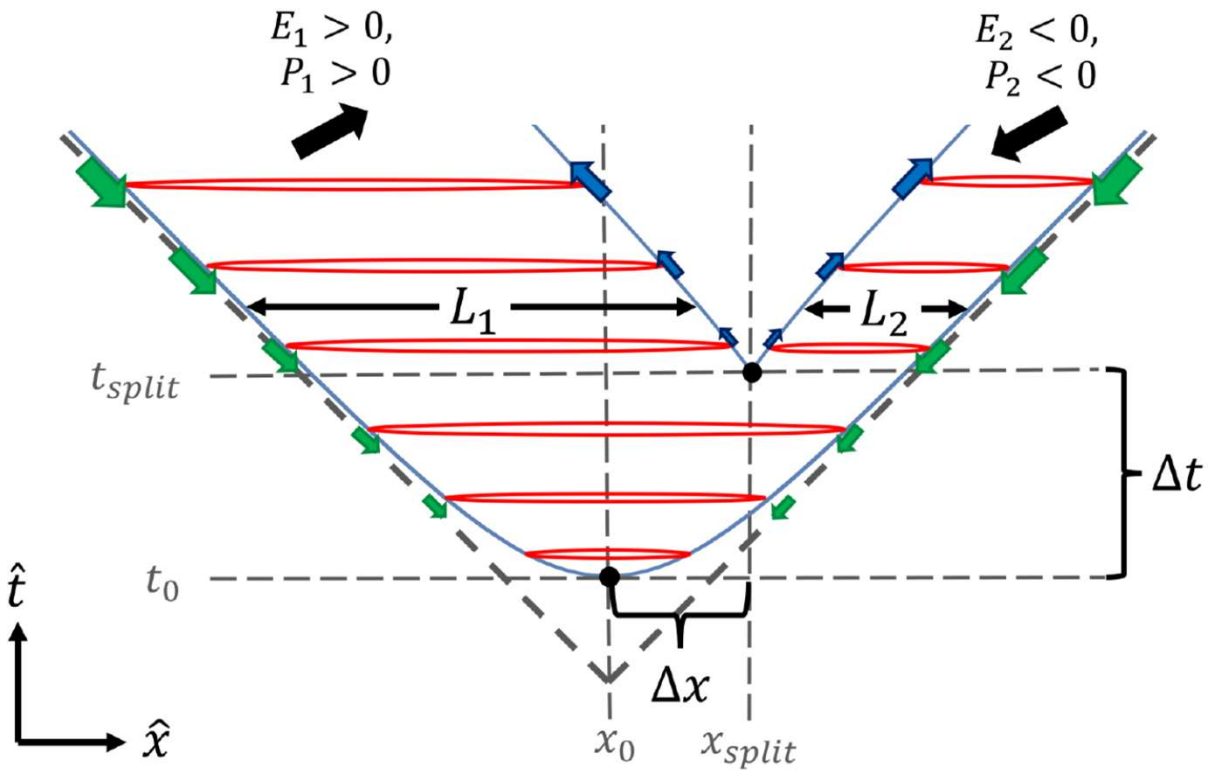

Stringy energy that are entangled with a negative energy.

With Uri Peleg and Paul Steinhardt we've just started to explore this.

Much work to be done:

Time dependence also in astro…

The adventure is just beginning