Title: Dynamics and the Cosmological Constant Problem

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Abstract: TBA

Dynamics and the Cosmological Constant Problem

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PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

May 27, 2009

Outline

1. Abbott's model (1985). And its problems
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Abbott's Model (85)

The action is $-\frac{1}{2}(\partial\phi)^2 + \epsilon\phi + \frac{1}{16\pi^2}\frac{\phi}{f}\mathrm{Tr}(F \wedge F)$

Instantons induce a potential: $V = \epsilon\phi + M^4\cos(\phi/f) + V_{ren}$

The renormalized CC term

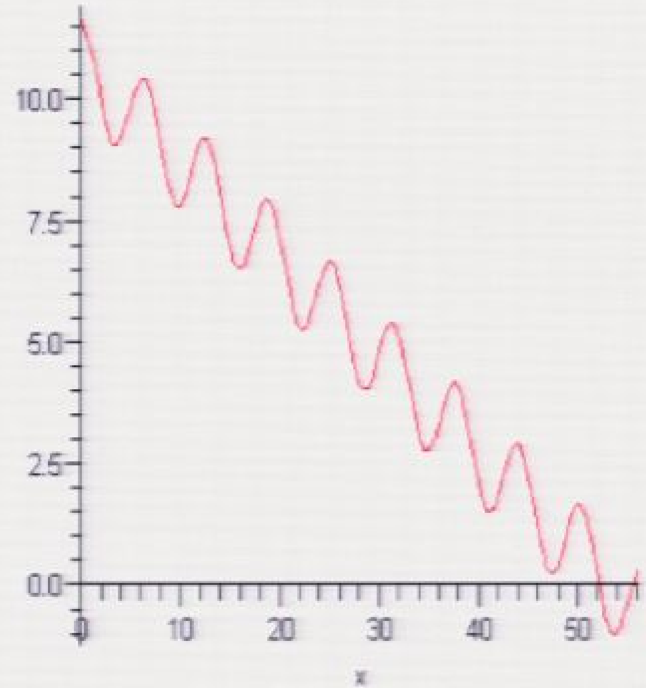
When $\epsilon = 0$ we have the symmetry $\phi \to \phi + 2\pi n f$

⇓

$|\epsilon| \ll 1$ is technically natural. (similar to the mass of the electron)

- Small M is natural.

Also at the quantum level the potential looks like:



- In quantum mechanics the local minima are on equal footing.

- Here the situation is more interesting:

Hawking temperature in de-Sitter is $T_H \sim \sqrt{V}$.

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The decay rate is $\Gamma \sim M^4 \exp(-1/V)$ ➡ Most of the time at small CC.

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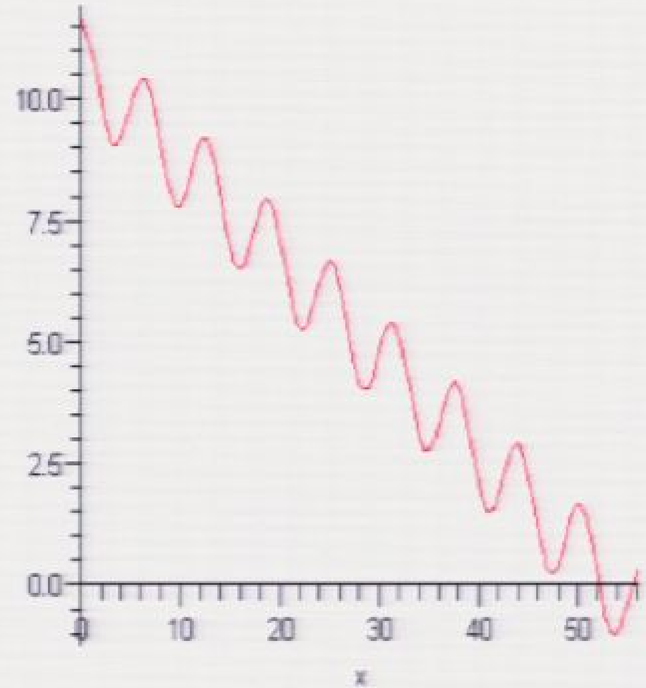

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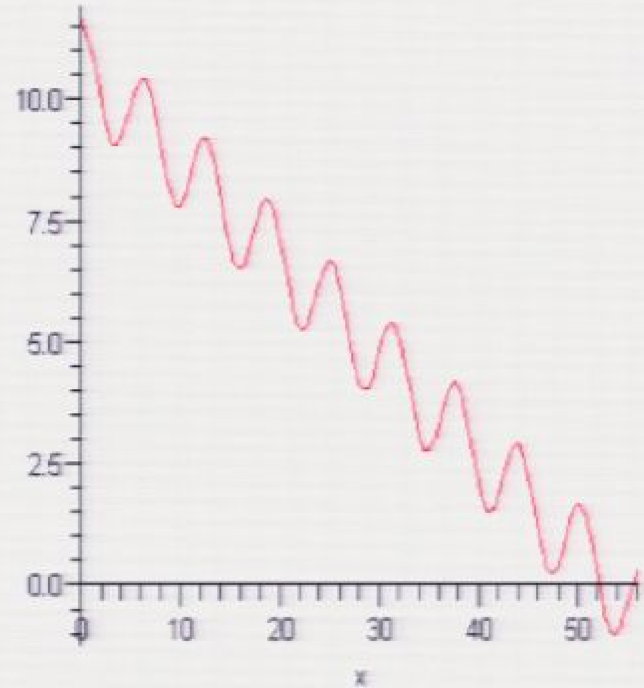

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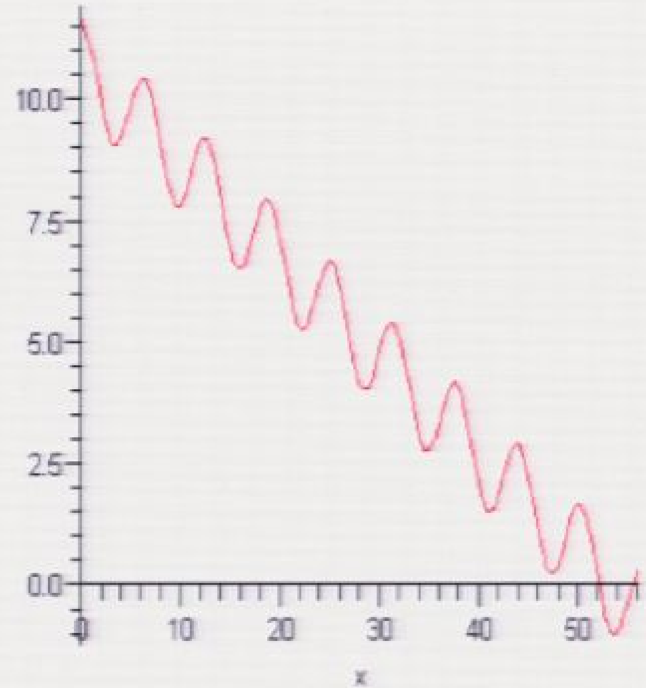

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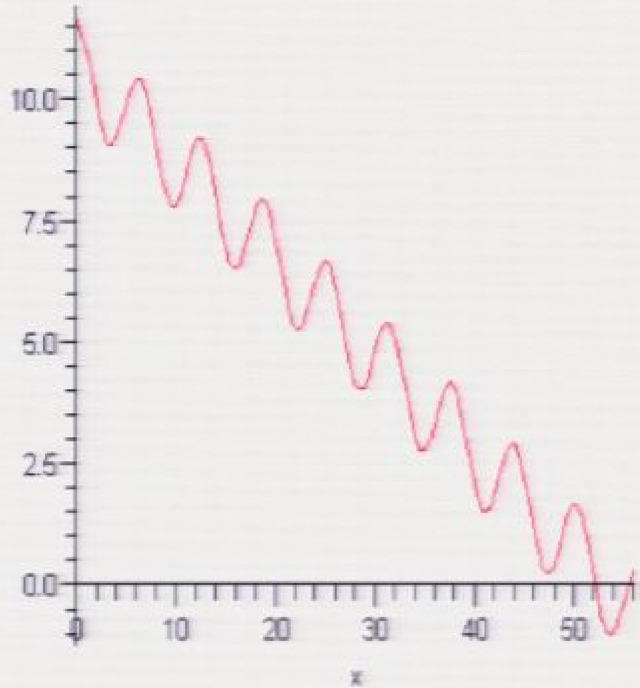

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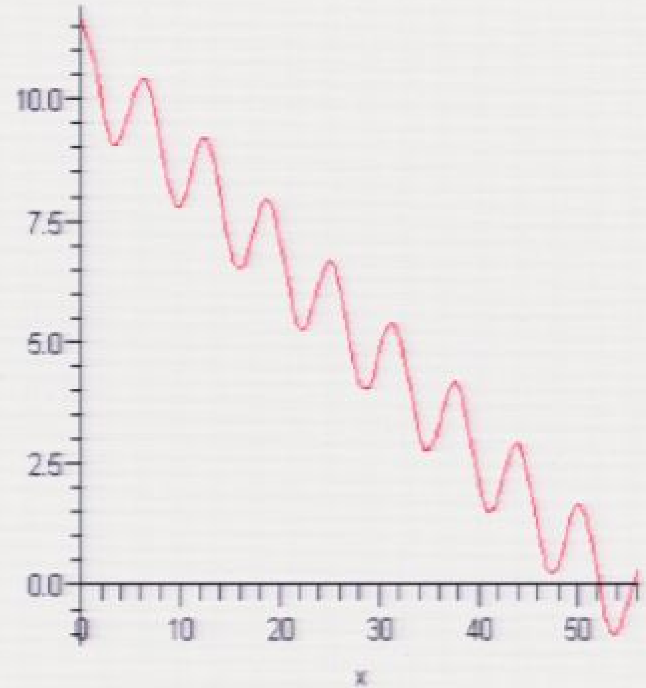

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Cannot be realized in string theory.

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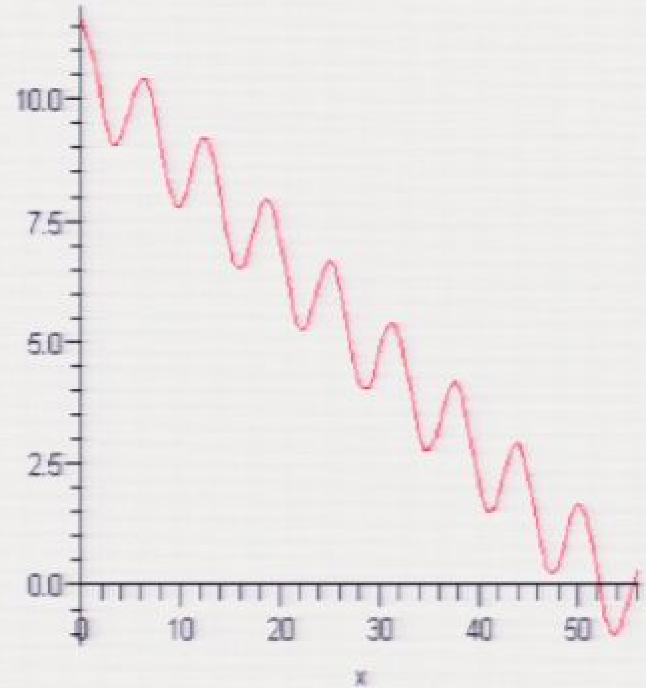

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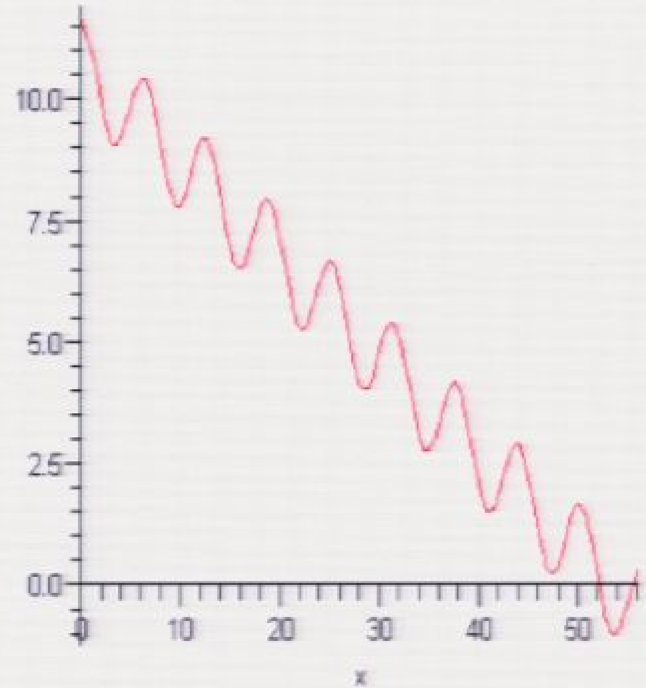

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In fact a linear term is easy to get:

The DBI action is

$$S_{DBI} = -\int \frac{d^{p+1}\xi}{(2\pi)^p} \alpha'^{-(p+1)/2} e^{-\Phi} \sqrt{\det\left(G_{MN} + B_{MN}\right) \partial_\alpha X^M \partial_\beta X^N}$$

Denote $\int B$ by b we get

$$V(b) = \frac{\epsilon}{g_s (2\pi)^5 \alpha'^2} \sqrt{\ell^4 + b^2}$$

which for large b is linear.

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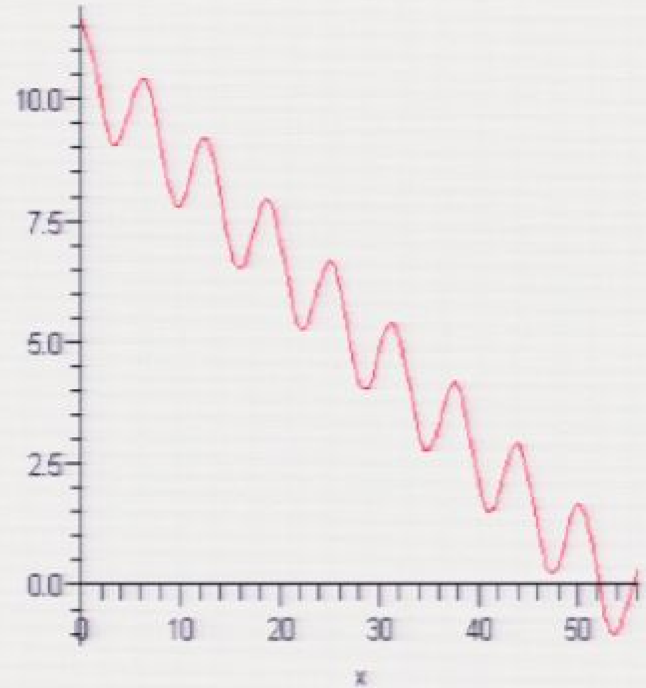

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What about the empty universe problem?

Let's modify Abbott's model in the following way:

$$S = S_{EH} + S_{\text{relaxation}} + S_{\text{inflation}}$$

The relaxation action is a simpler version of Abbott's action

$$S_{\text{relaxation}} = \int d^4x \sqrt{-g} \left(-\frac{1}{2}(\partial\psi)^2 - V_{\text{ren}} - V(\psi) \right)$$

where $V(\psi) = \epsilon\,\psi$.

Much like in Abbott's case the vacuum energy is reduced slowly.

The challenge is to evade the emptiness problem by converting the potential energy into kinetic energy.

$S_{\text{inflation}}$ is designed to fix that while making sure that the vacuum energy at the end of inflation is small.

That is $S_{\text{inflation}}$ makes

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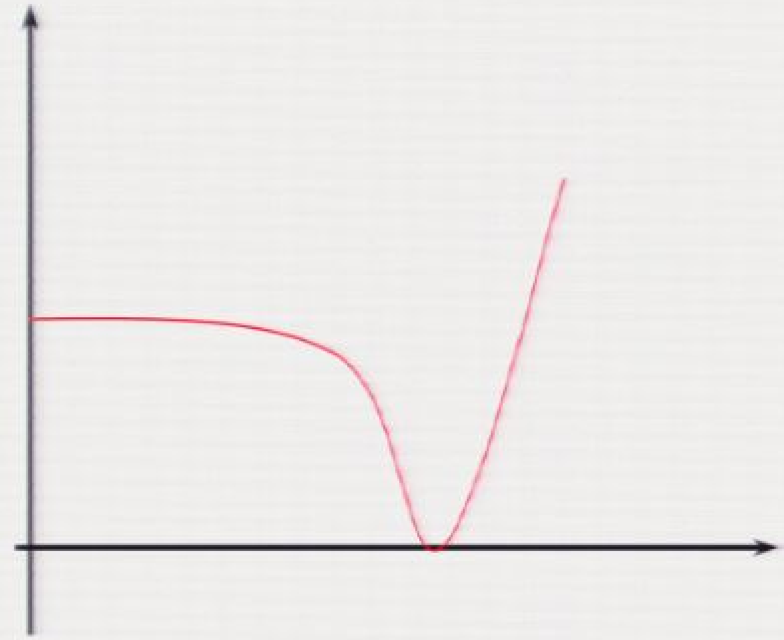

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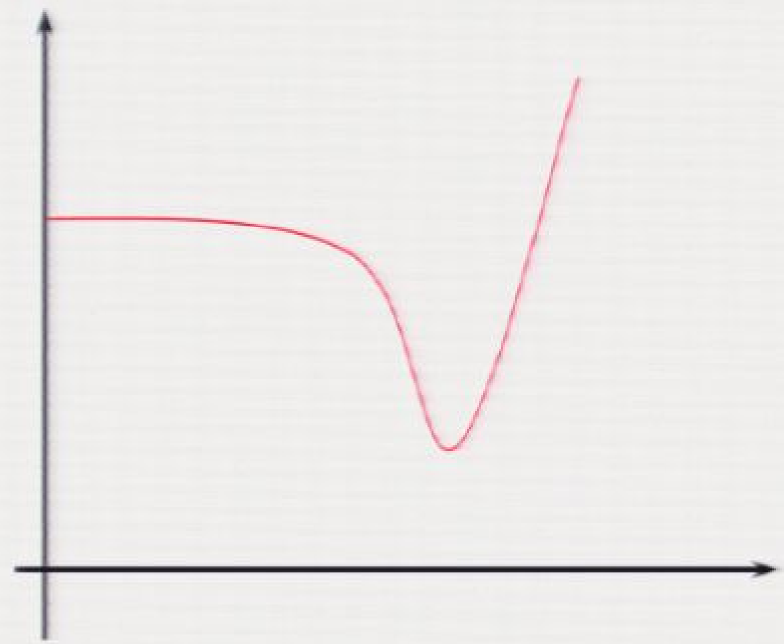

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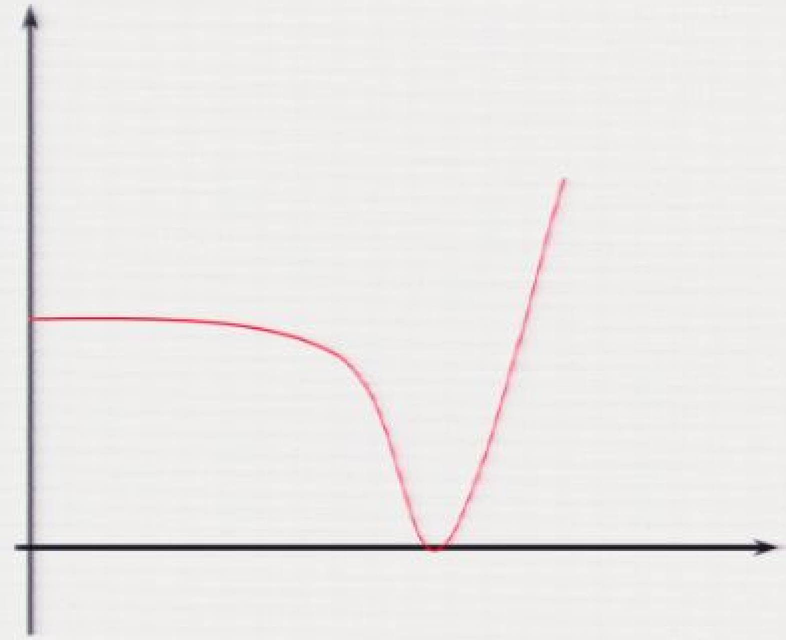

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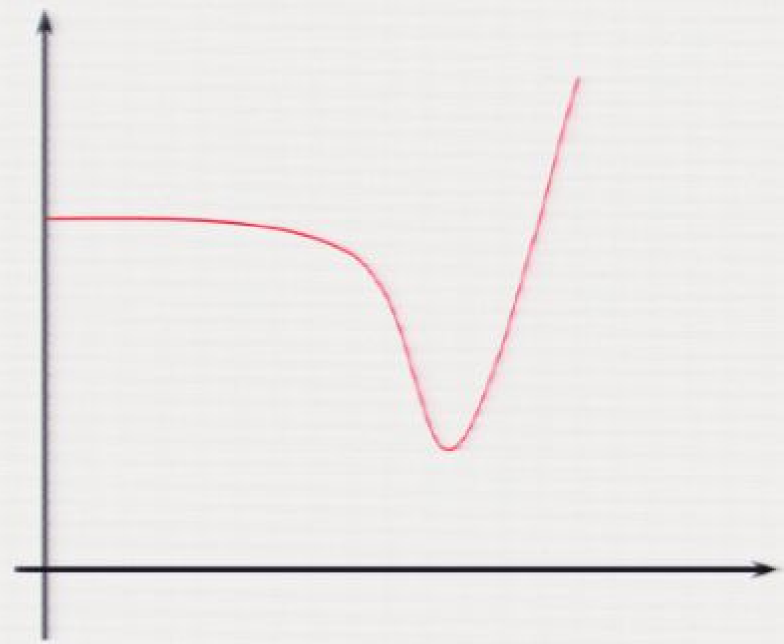

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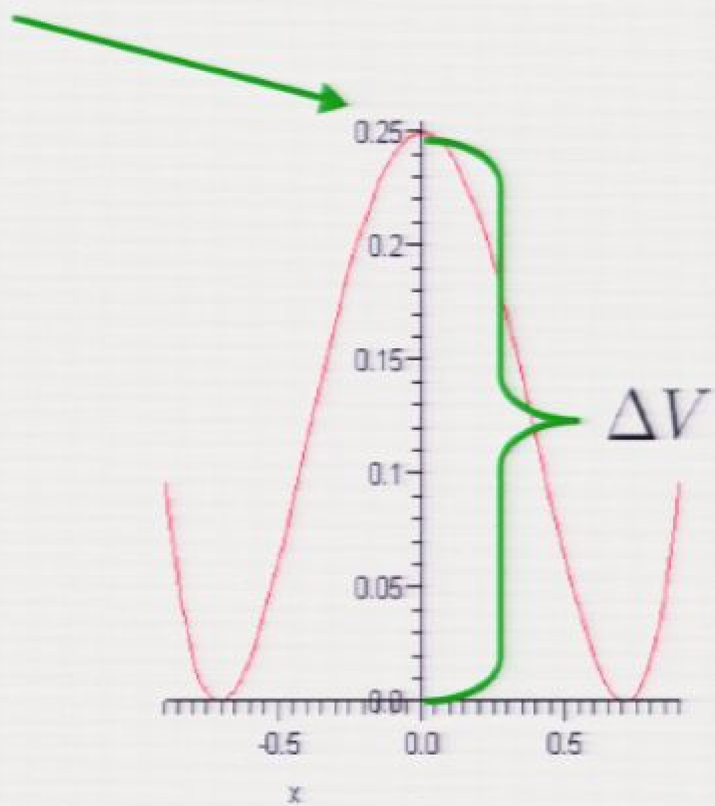
The potential is designed to have the following properties:

$$\gamma \equiv -\left.\frac{d^2V(\phi)}{d\phi^2}\right|_{\phi=0} > 0 \quad \text{and} \quad \Delta V \equiv V_{max} - V_{min} = \frac{\gamma}{4}$$



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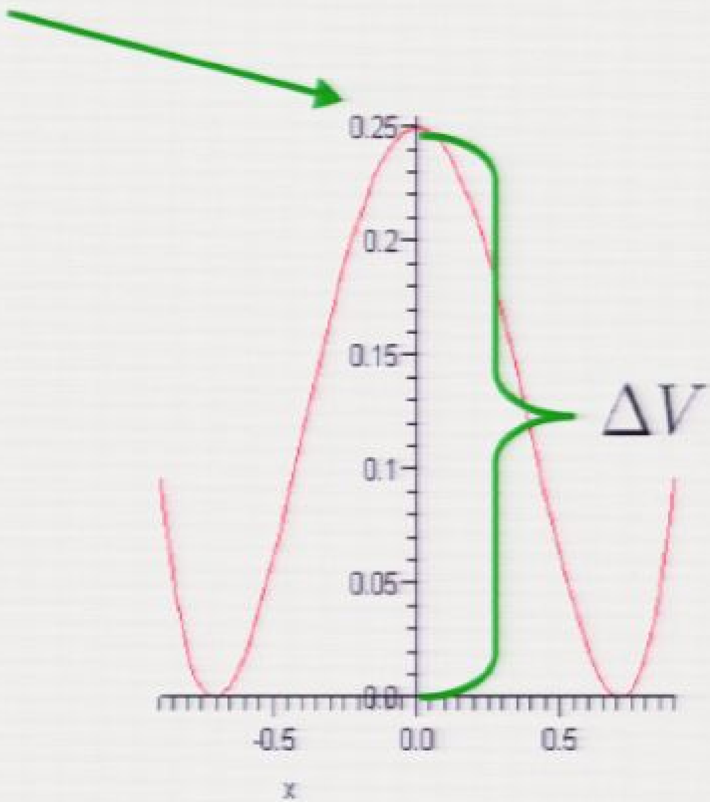

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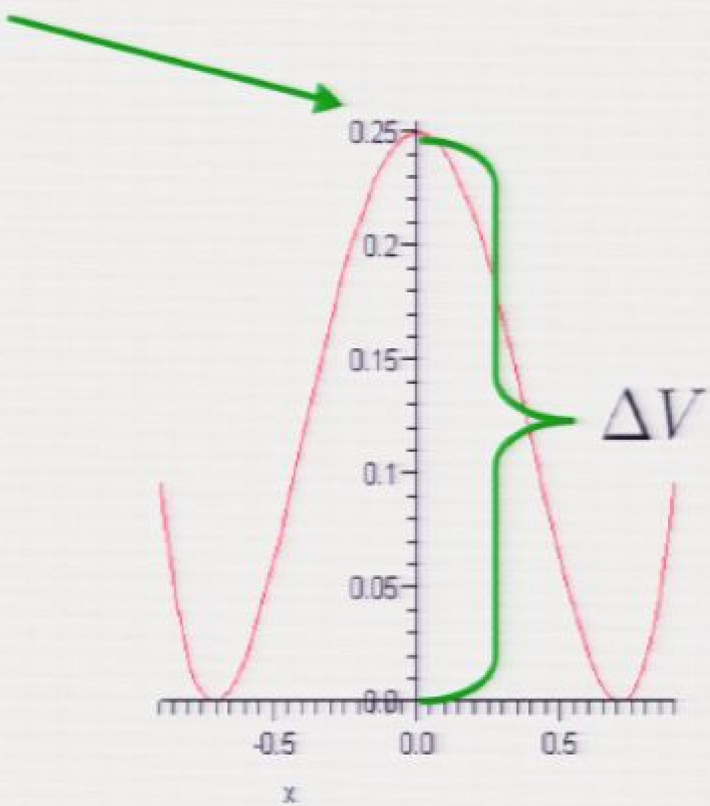

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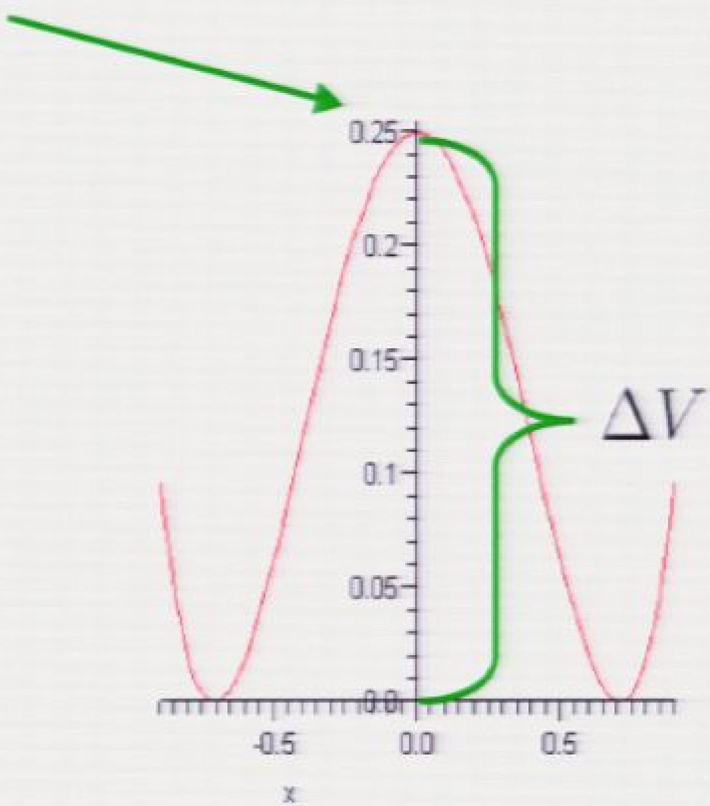

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So the picture is:

Hidden sector

TeV SUSY

Gauge mediation

Gravity mediation

(N) MSSM

ϕ sector

$M^{\phi}_{\mathrm{SUSY}} \sim 10^{-30}$

Problems with the model:

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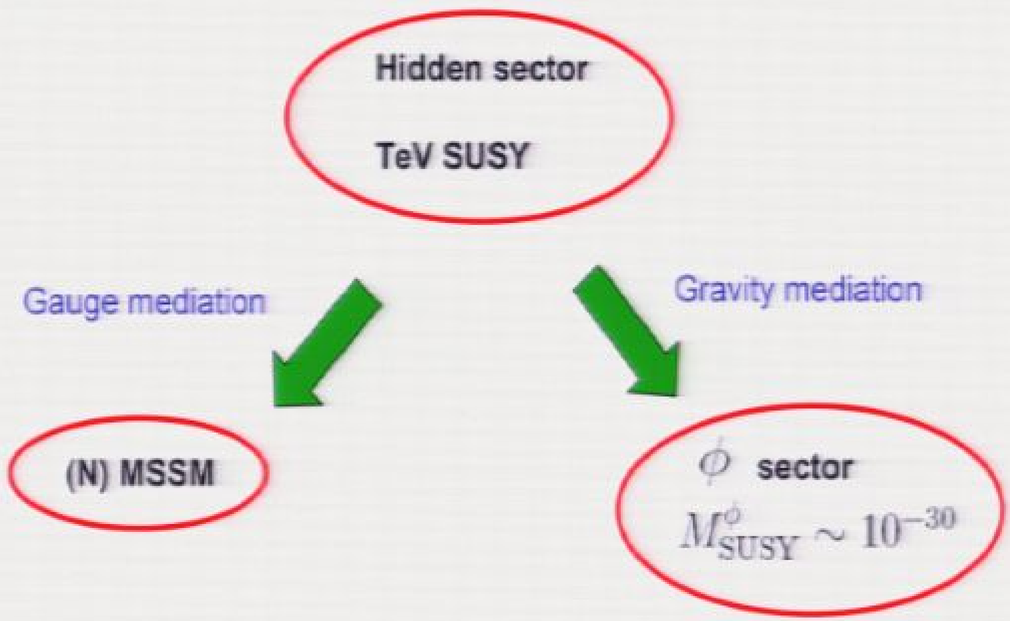

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TeV SUSY

Gau

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Re-heating coupling

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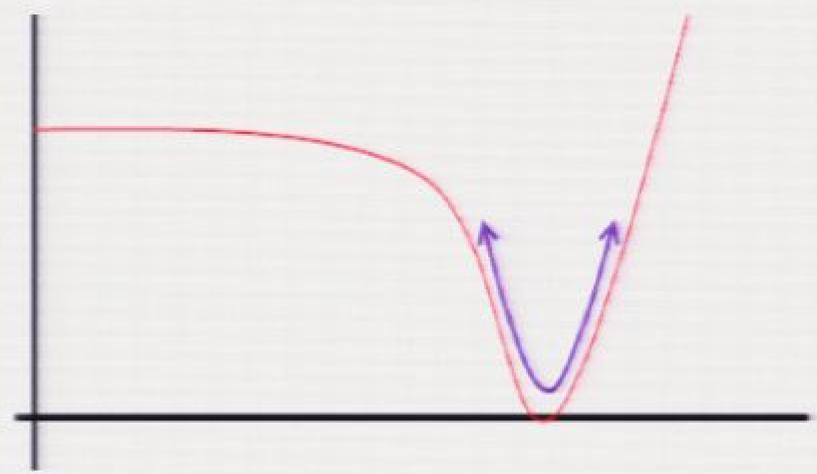

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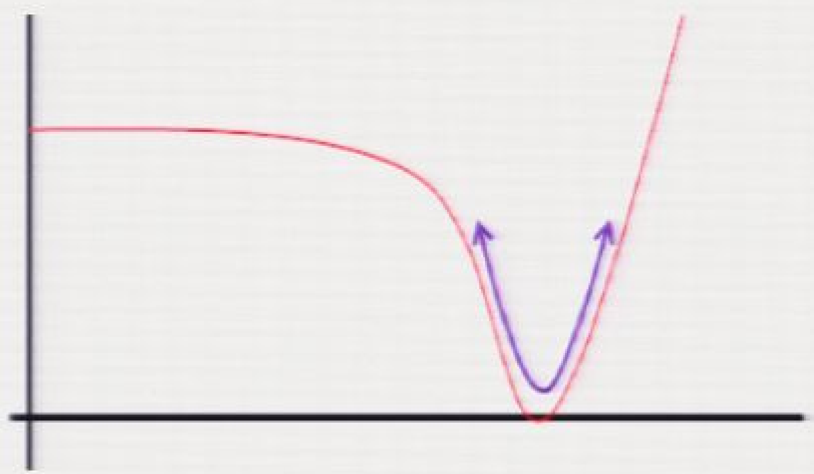

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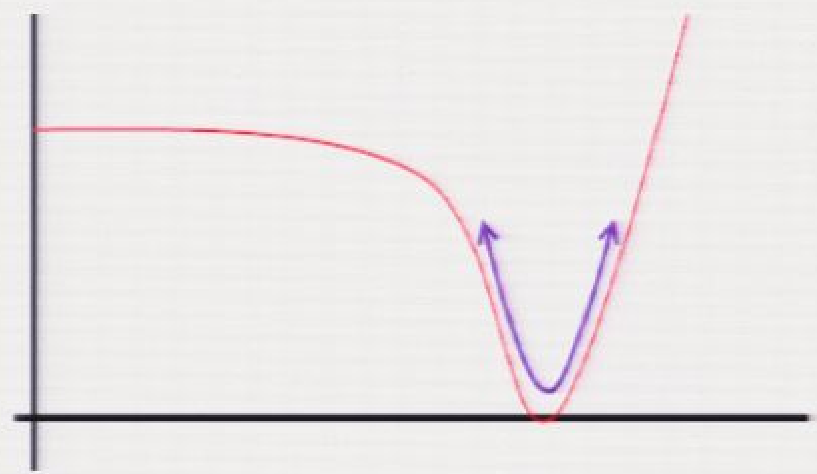

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Suppose that for some reason $V'(\phi) < 0, \; V(\phi) > 0 \text{ and } V(\infty) = 0$

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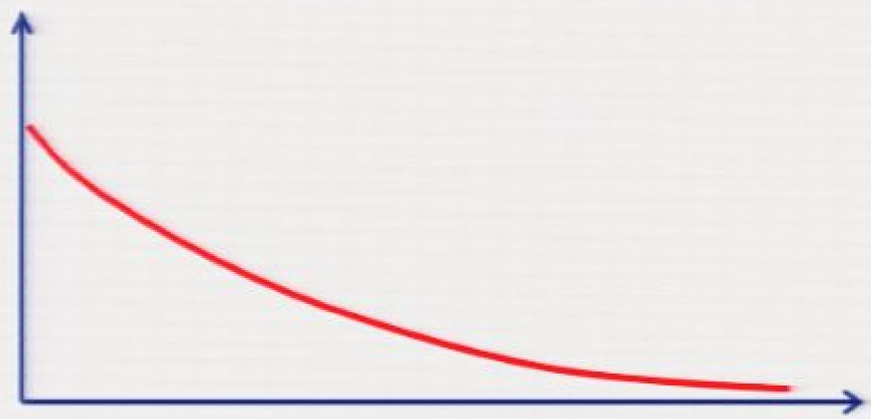

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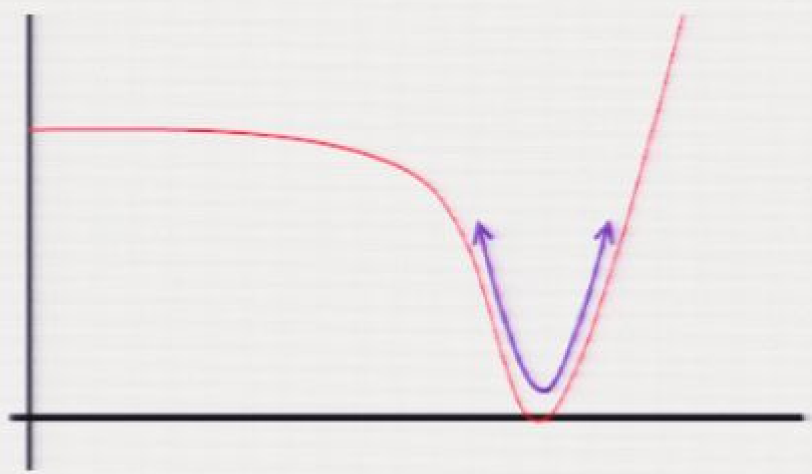

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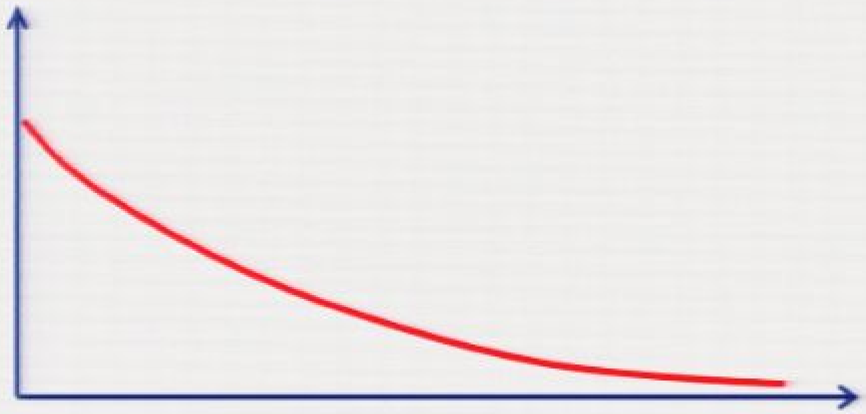

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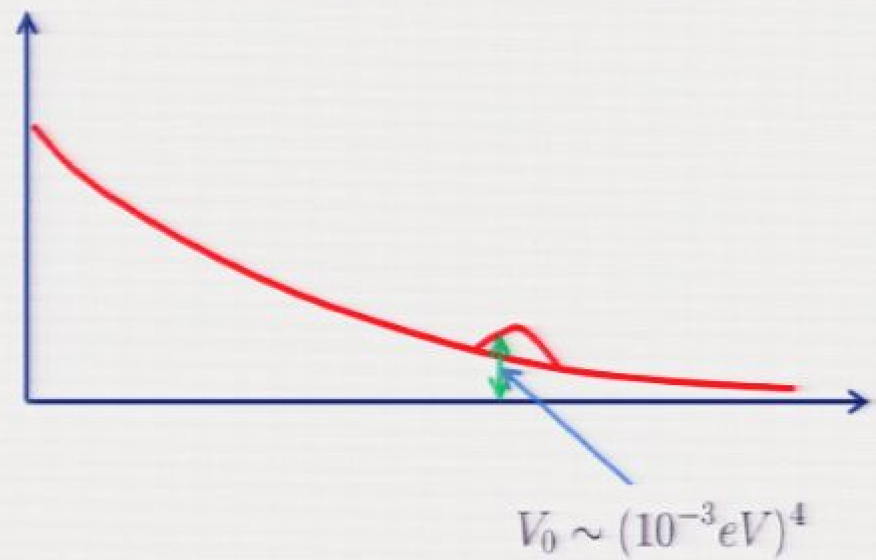

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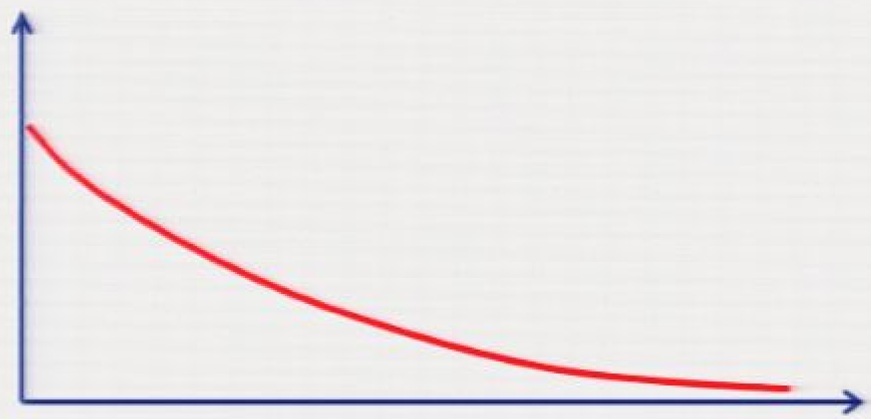

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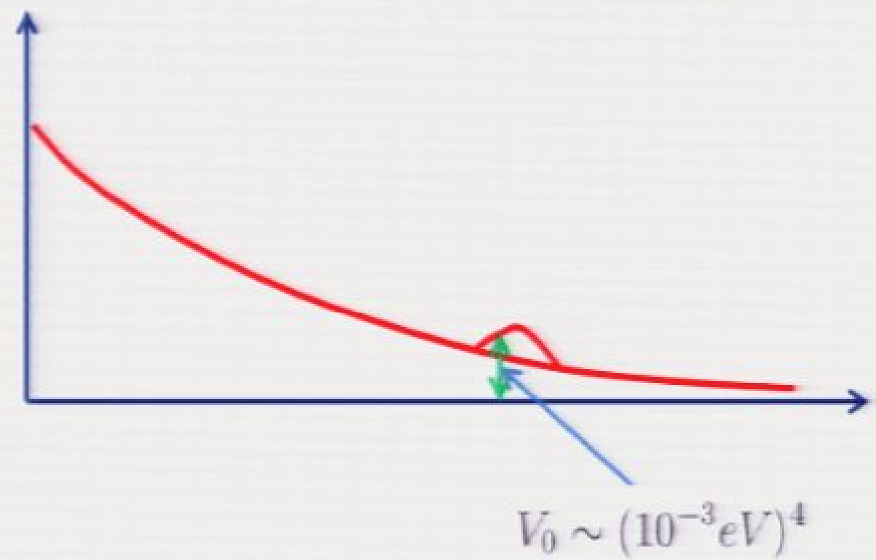

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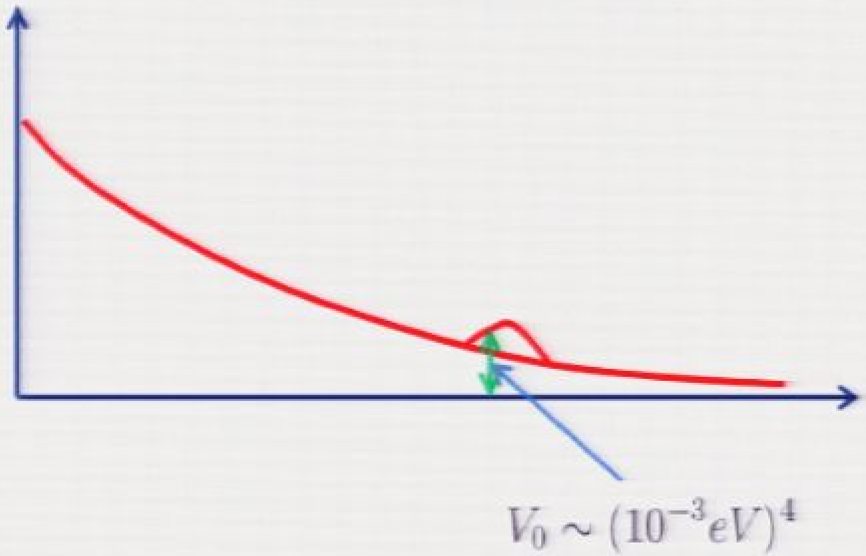

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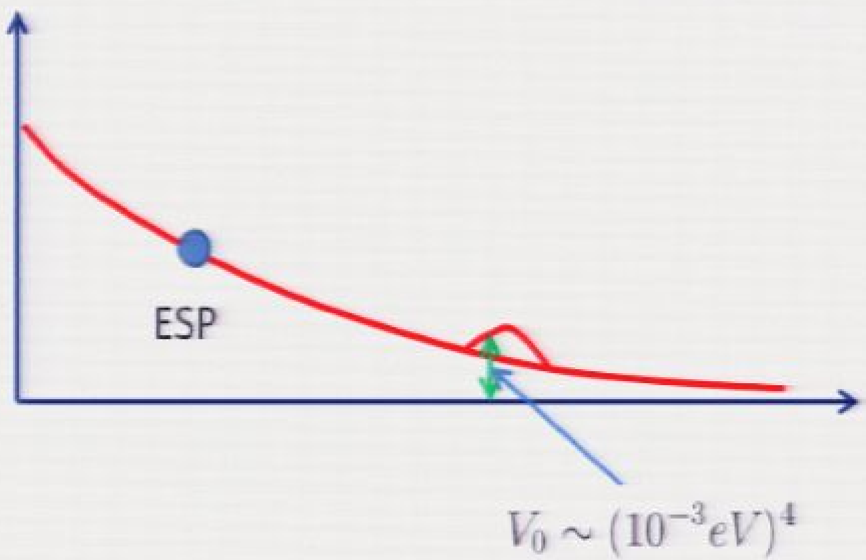

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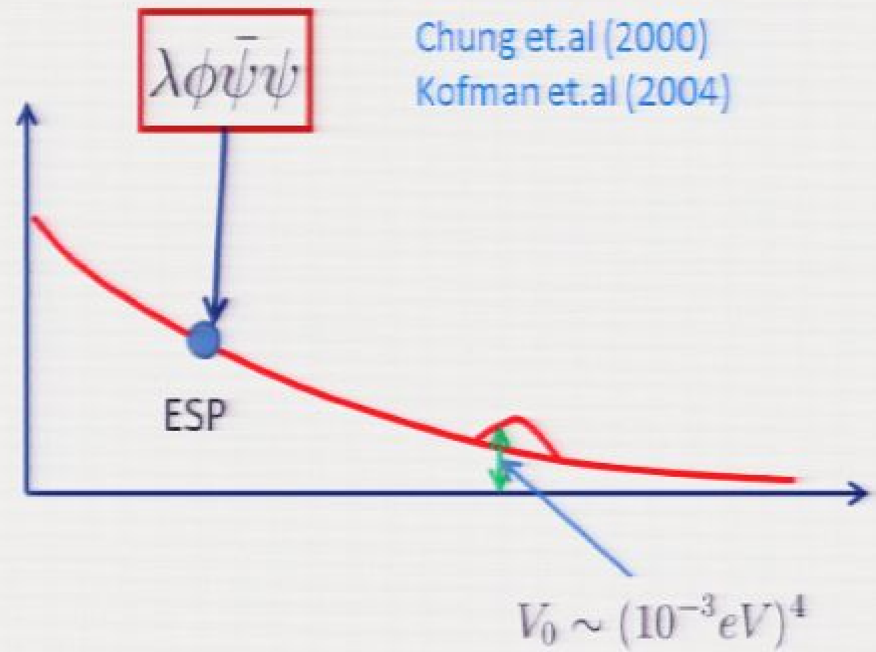

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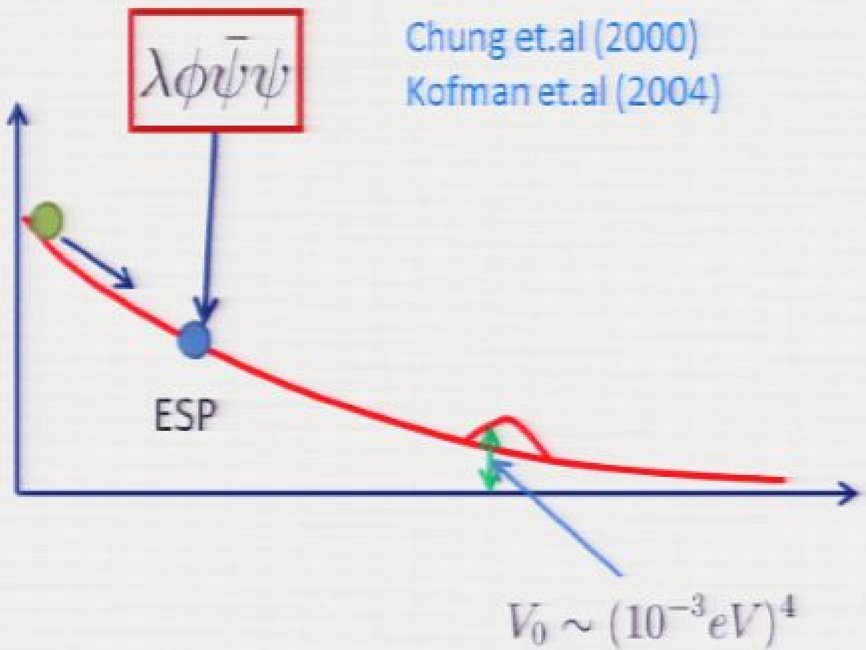

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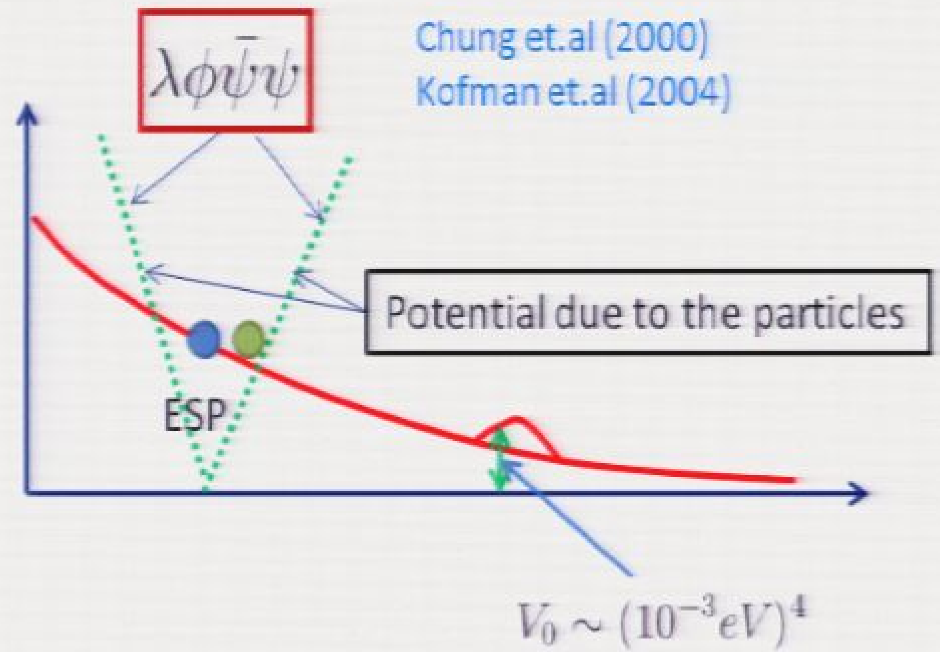

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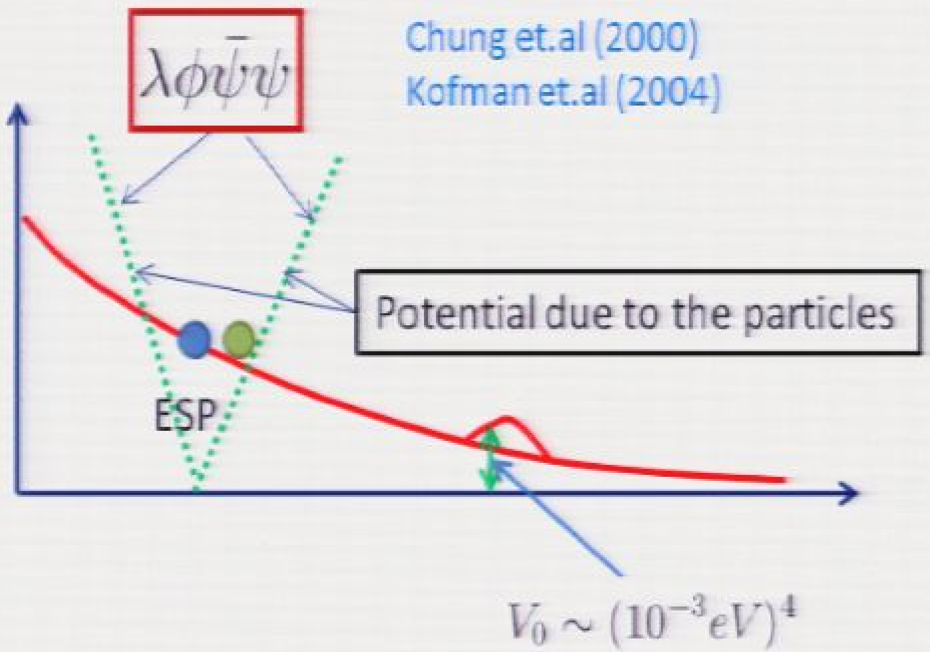

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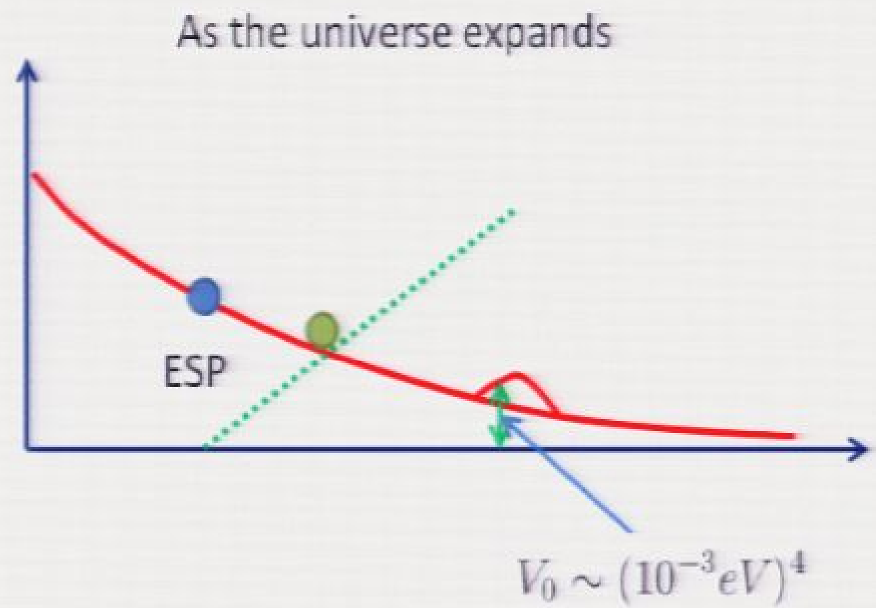

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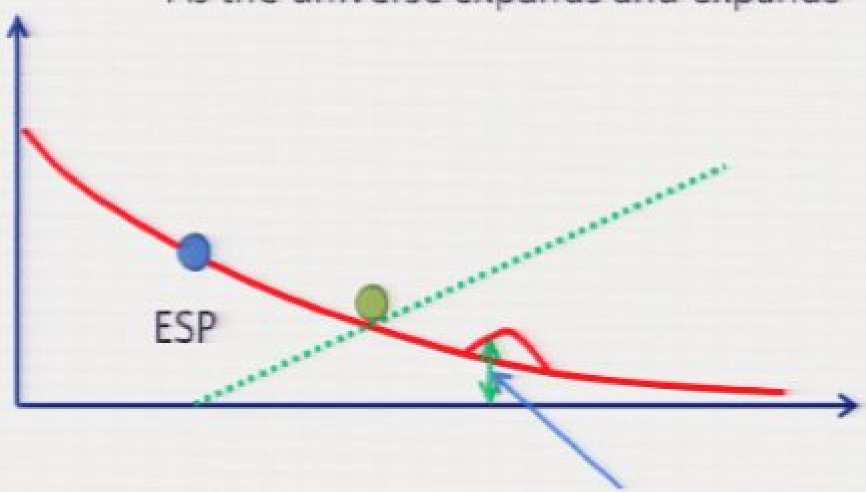

$V_0 \sim (10^{-3} eV)^4$

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We end up with a small CC

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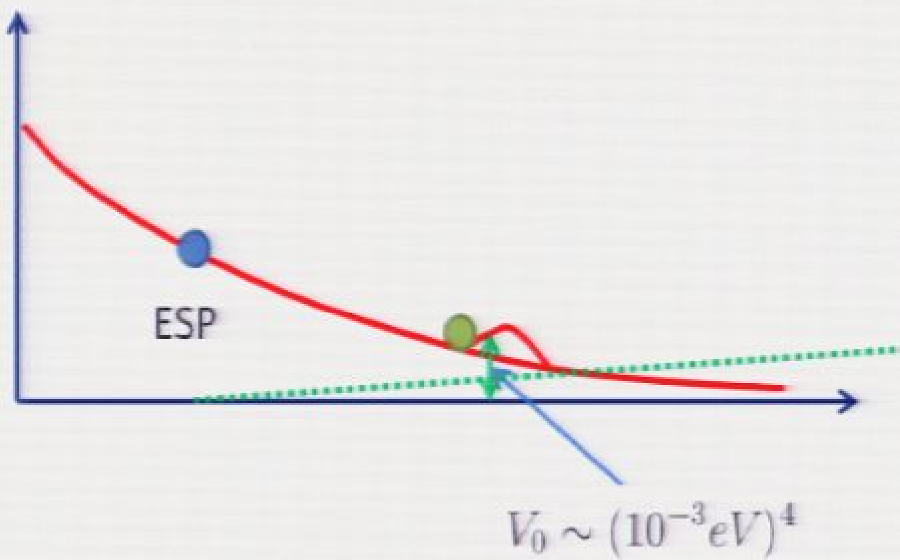

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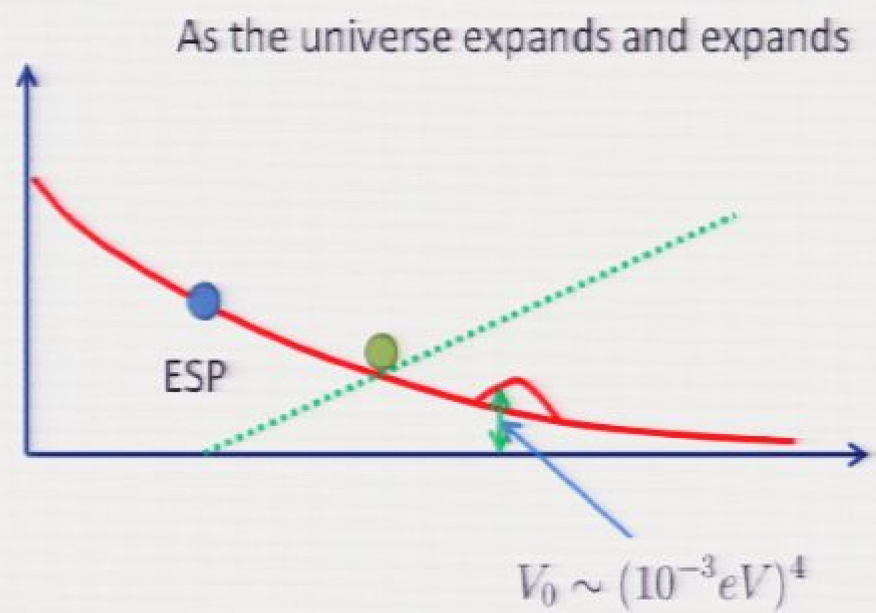

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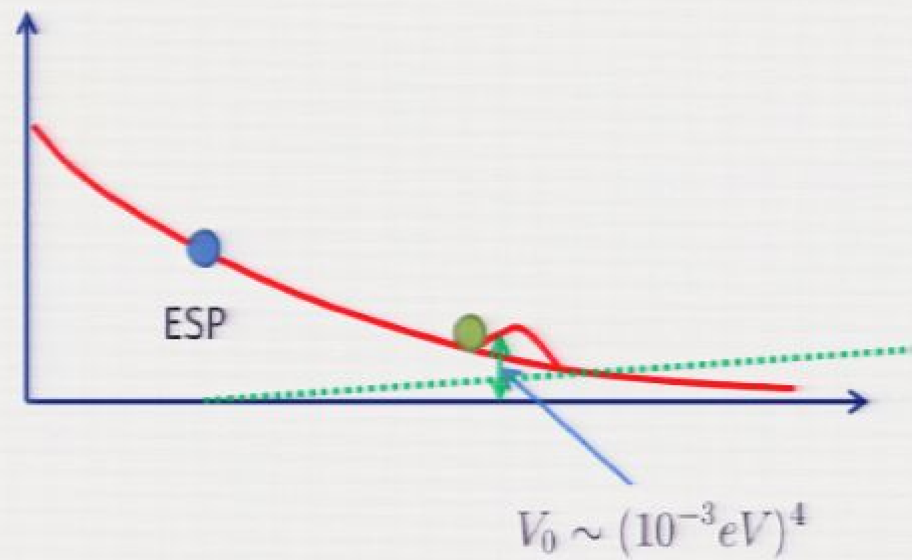

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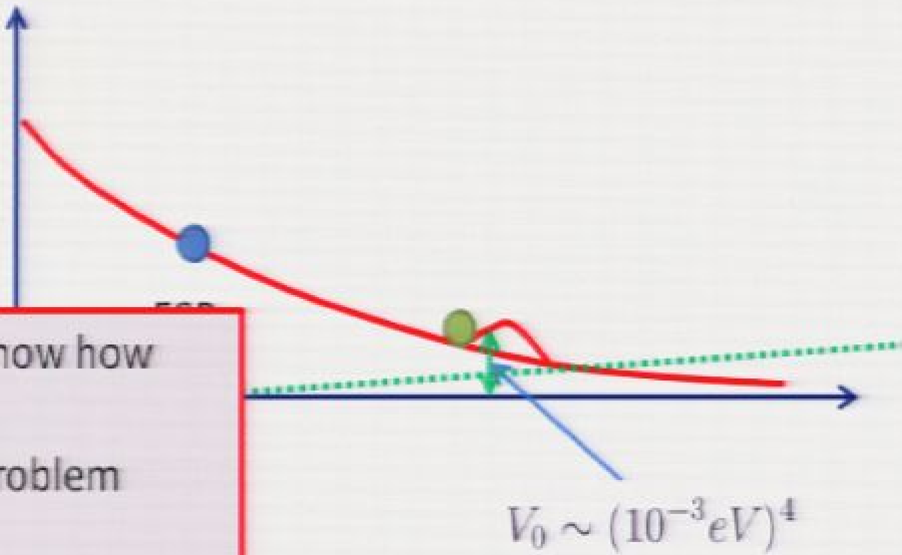

Since we don't know how

to solve the 1st problem

we move to the 2nd approach

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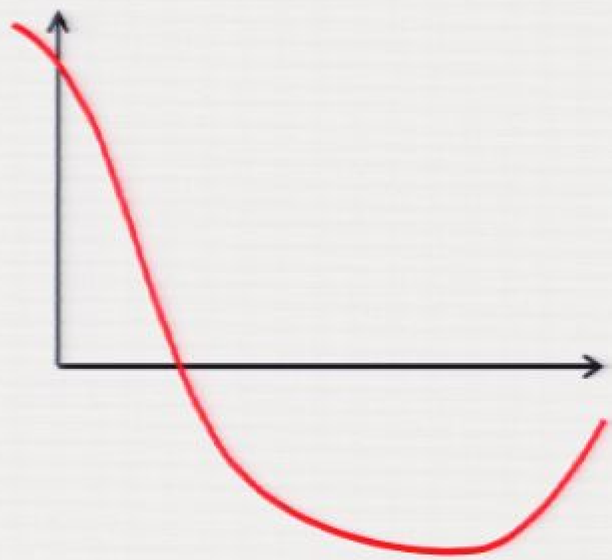

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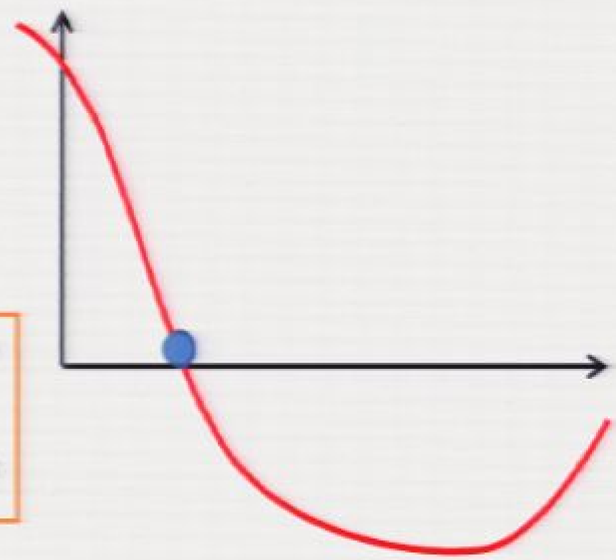

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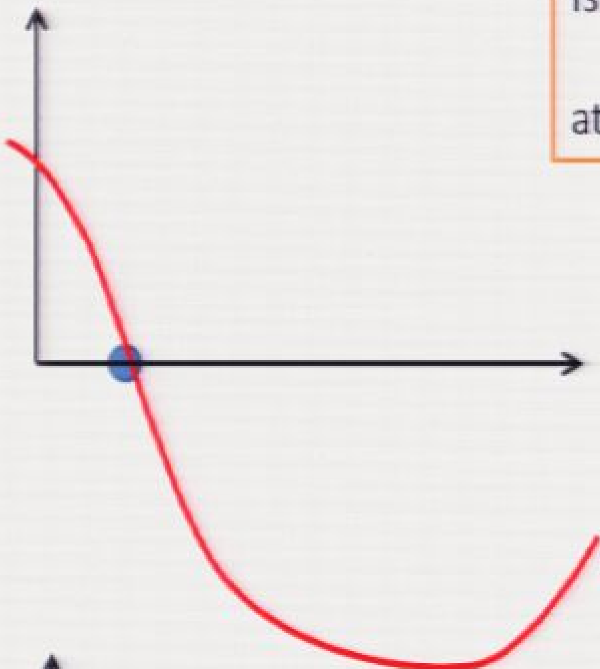

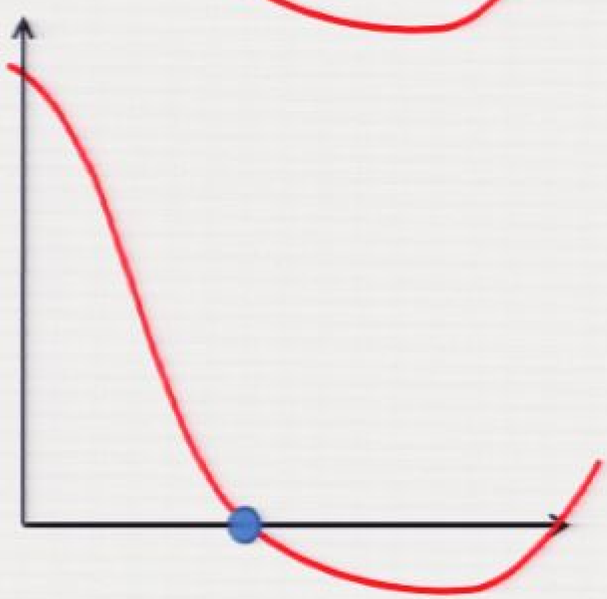

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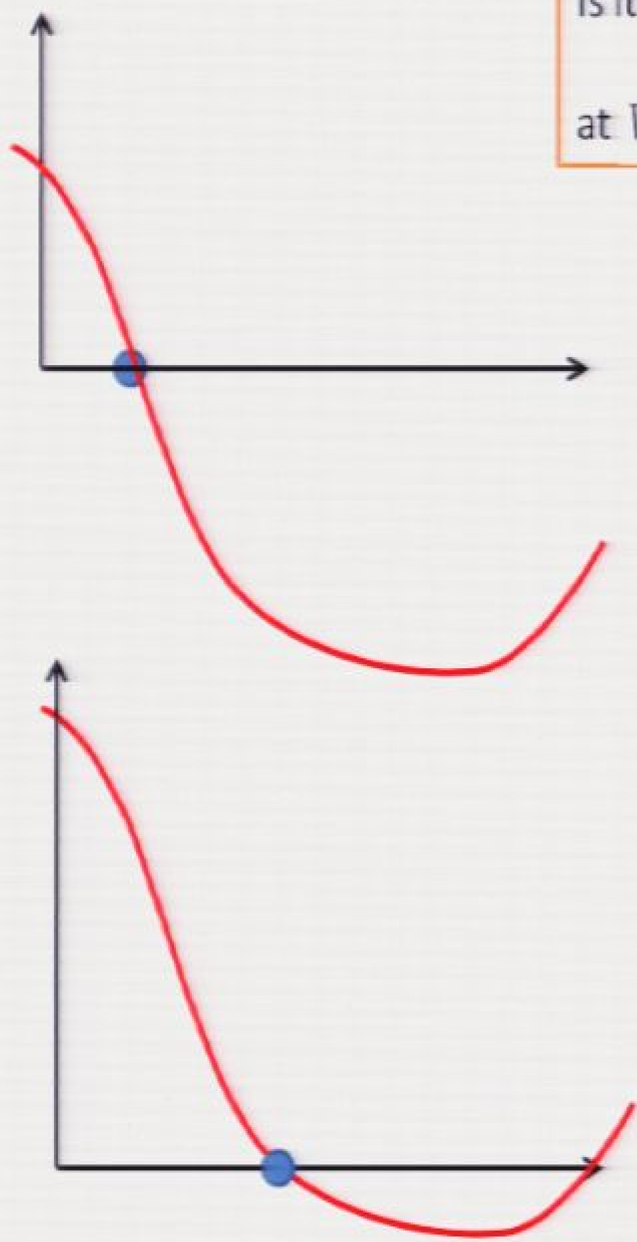

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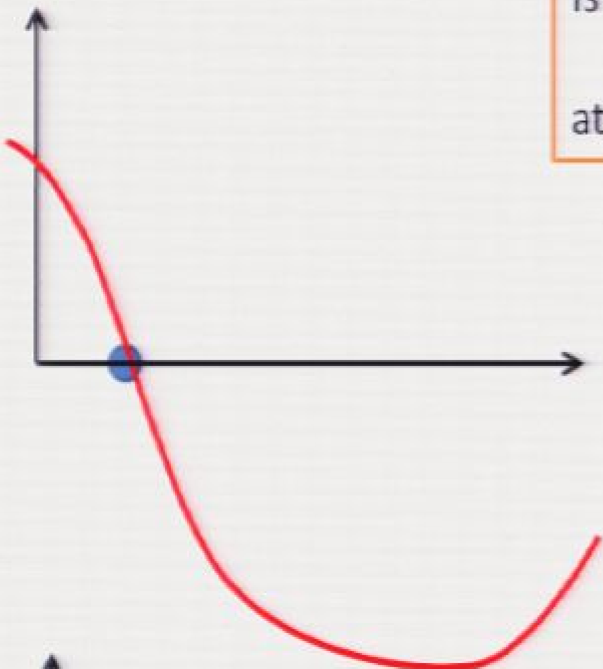

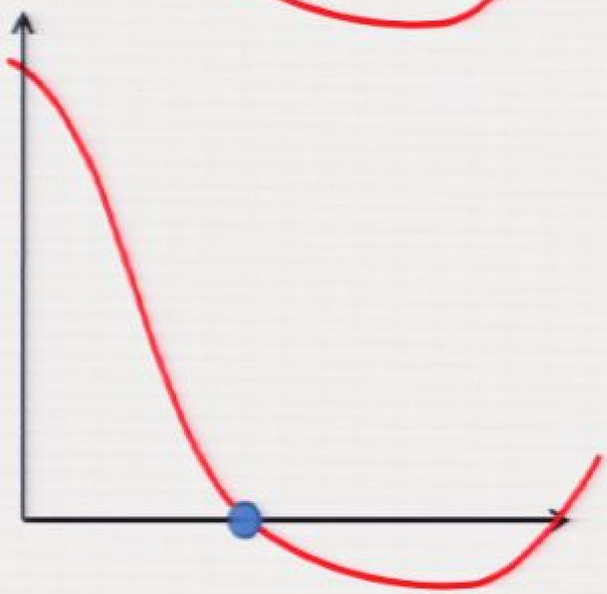

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Right now I see no reason

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So we move on to take II

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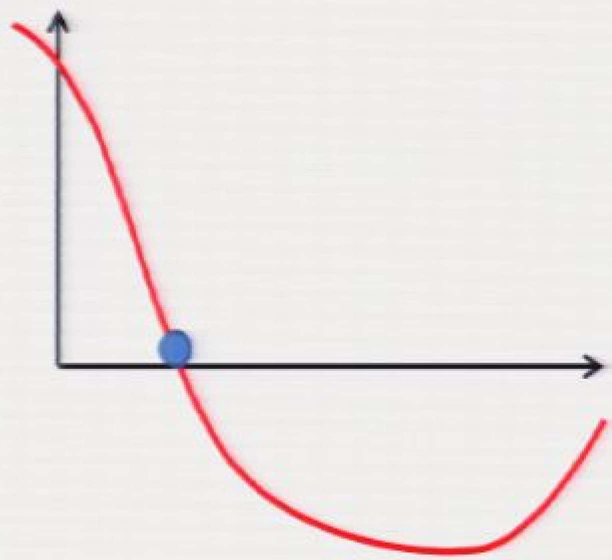

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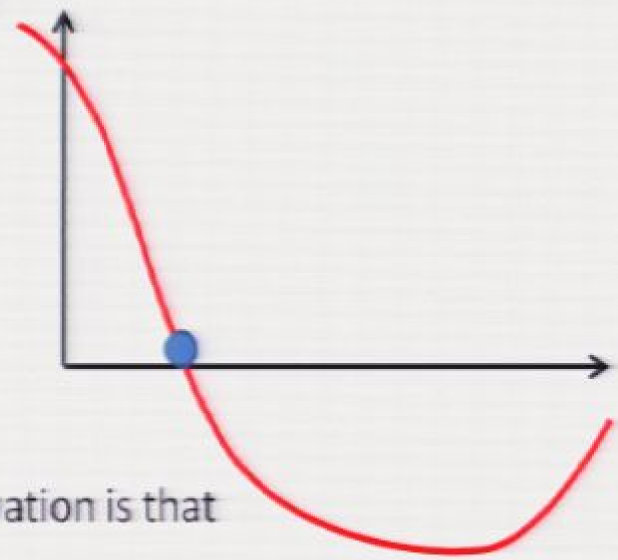

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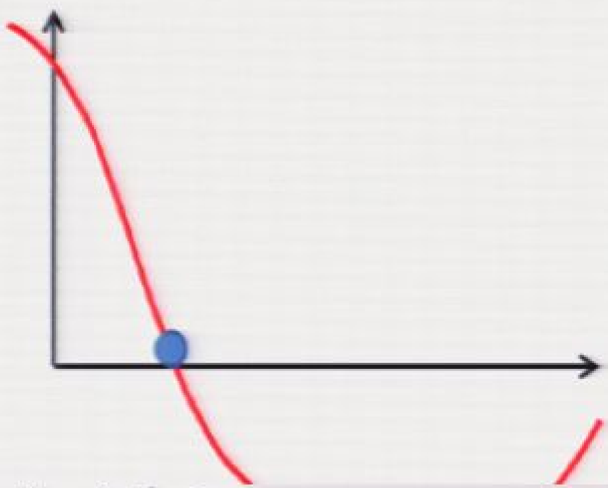

A possibly interesting observation is that we want $V_{ESP} = 0$ only during the period after the end and before reheating.

During this period the only contributions to the energy density are due to

1- Potential energy.

2- Kinetic energy of the inflaton.

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   Seem to work much better.

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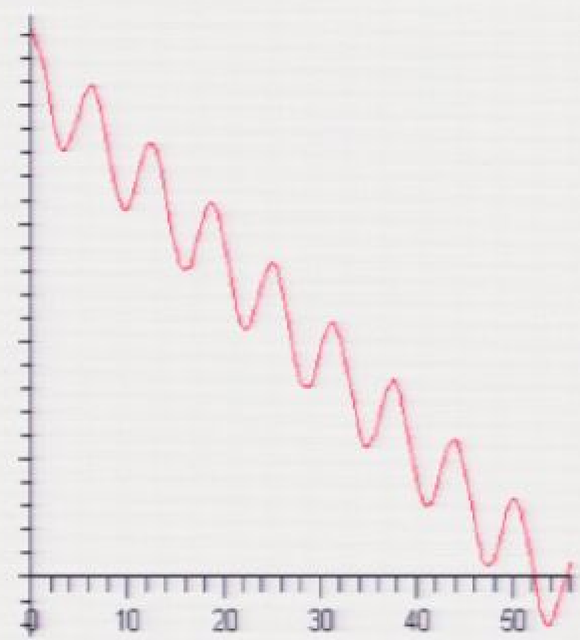

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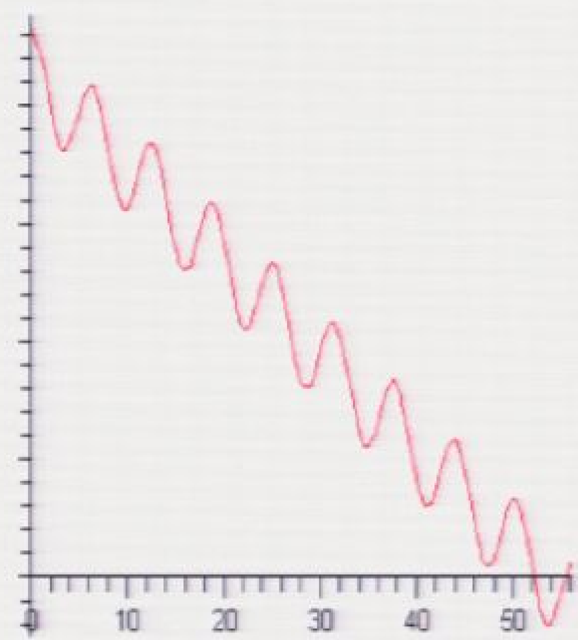

Probably both are needed:

(A) Will do the job at high temperature

and (B) when the universe cools down.

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