

Title: 13/14 PSI - Explorations in Cosmology - Lecture 14

Date: Apr 25, 2014 10:15 AM

URL: <http://pirsa.org/14040059>

Abstract:

False Vacuum EI

Last time: $S = \int d^4x \left[\frac{1}{2} (\partial\phi)^2 - V(\phi) \right]$

Today: $S = \int d^4x \sqrt{-g} \left[\frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - V - \frac{M_P^2}{2} R \right]$

Assumption: solution is $O(4)$ symmetric

$$ds^2 = d\xi^2 + \rho^2(\xi) d\Omega_3^2$$

$$S_E =$$

$$S_E = 2\pi^2 \int d\xi \left[\rho^3 \left(\frac{\dot{\phi}^2}{2} + V \right) + 3M_P^2 (\rho^2 \ddot{\rho} + \rho \dot{\rho}^2 - \rho) \right]$$

$\uparrow$
 angular
 integration

$\cdot = \partial_\xi$

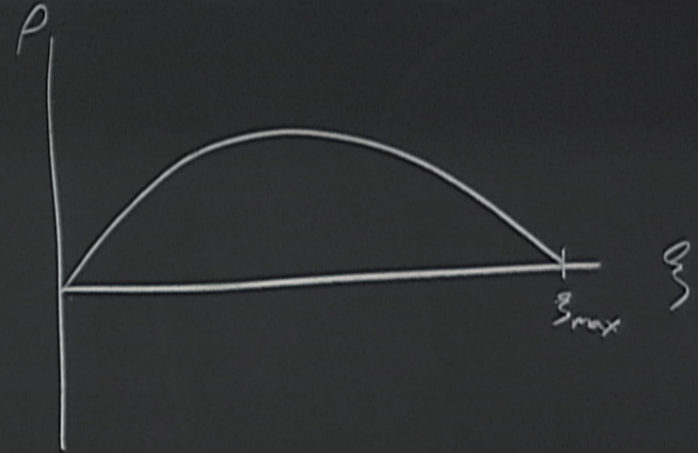
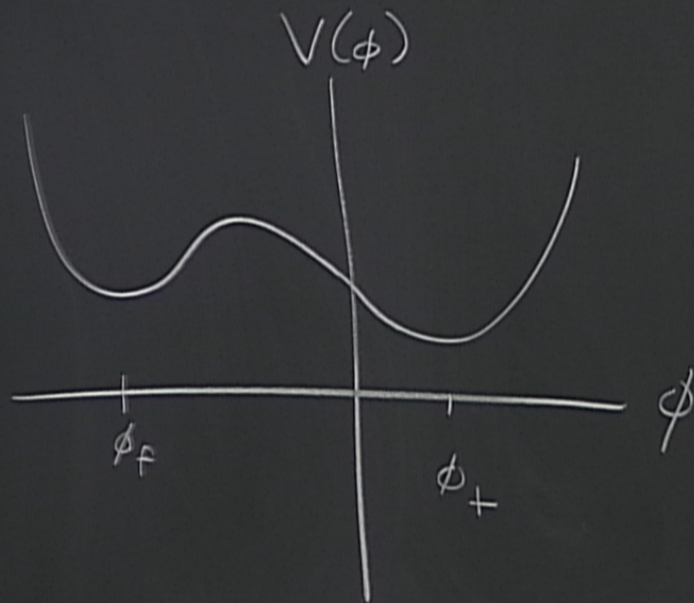
$\underbrace{\hspace{10em}}_{-\frac{M_P^2 R}{2}}$

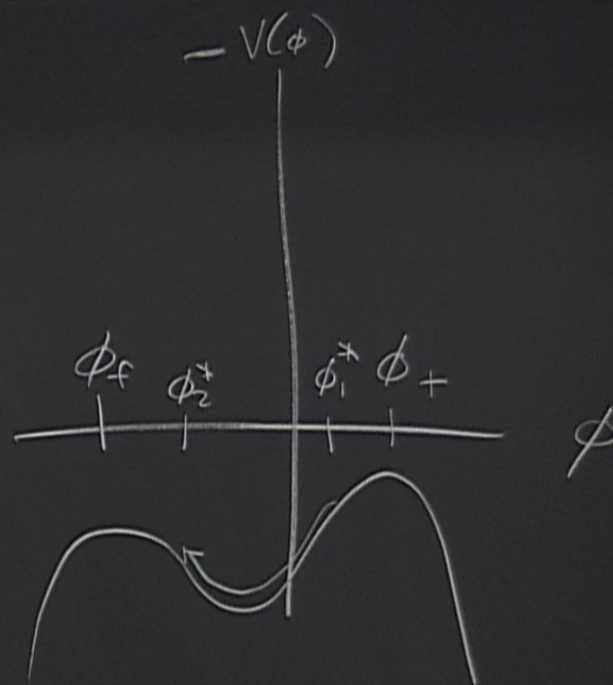
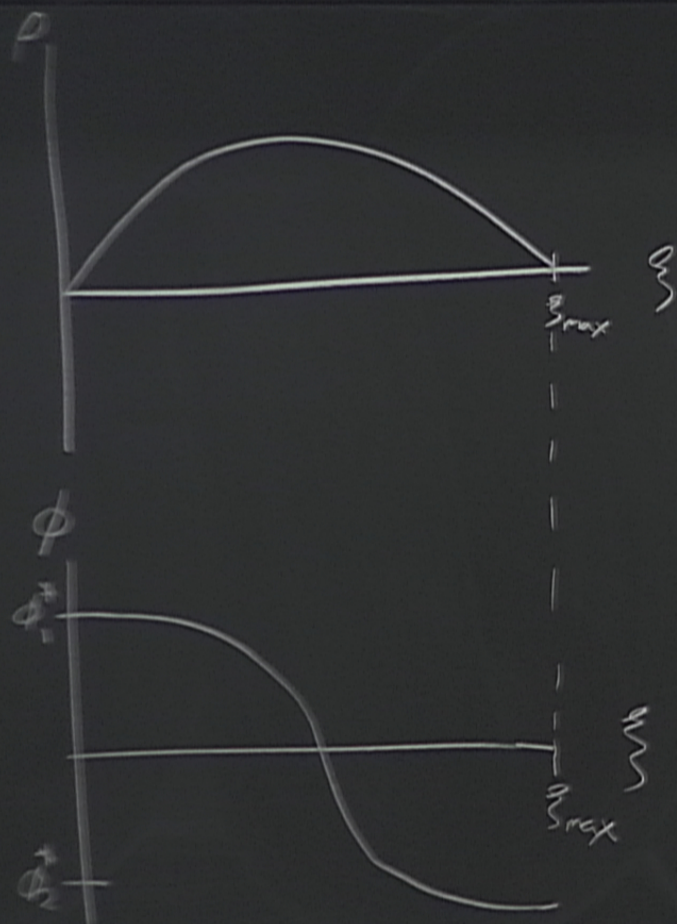
$$\text{EOM: } \ddot{\phi} + \frac{3\dot{\rho}}{\rho} \dot{\phi} - V' = 0$$

$$\xi\xi \text{ of EE: } \dot{\rho}^2 = 1 + \frac{\rho^2}{3M_P^2} \left(\frac{1}{2} \dot{\phi}^2 - V \right)$$

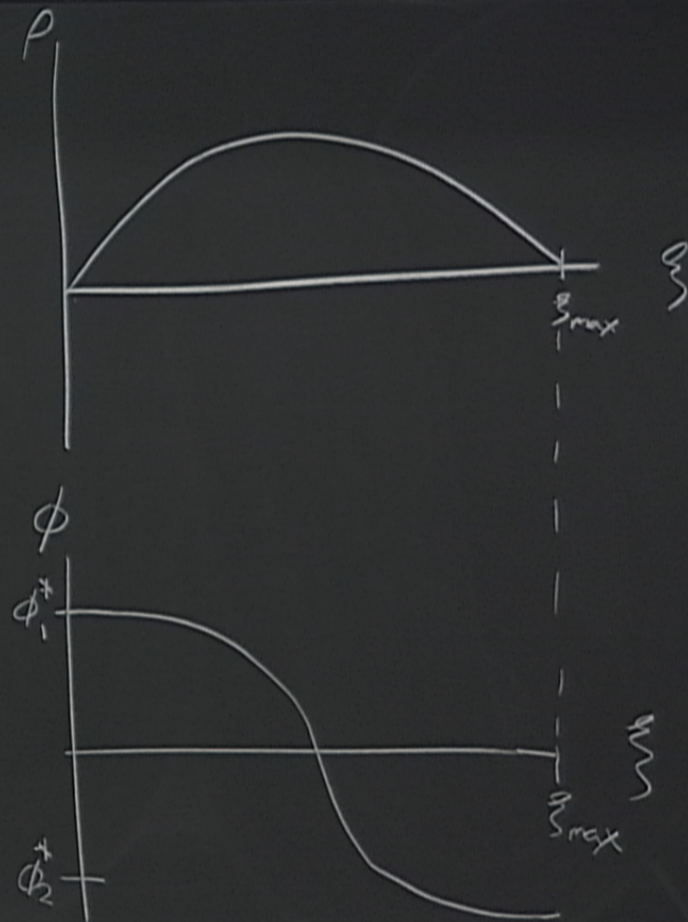
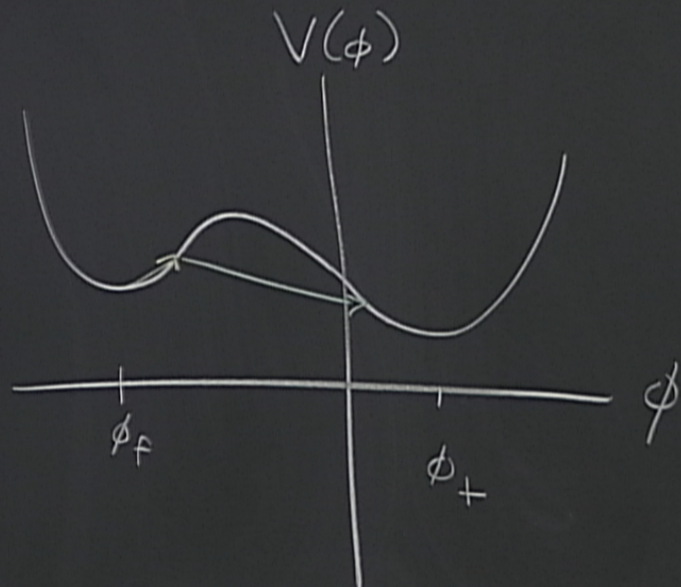
$$\rho(0) = 0 \xRightarrow{\text{EE}} \dot{\rho}(0) = 1 \xRightarrow{\text{EOM}} \dot{\phi}(0) = 0$$

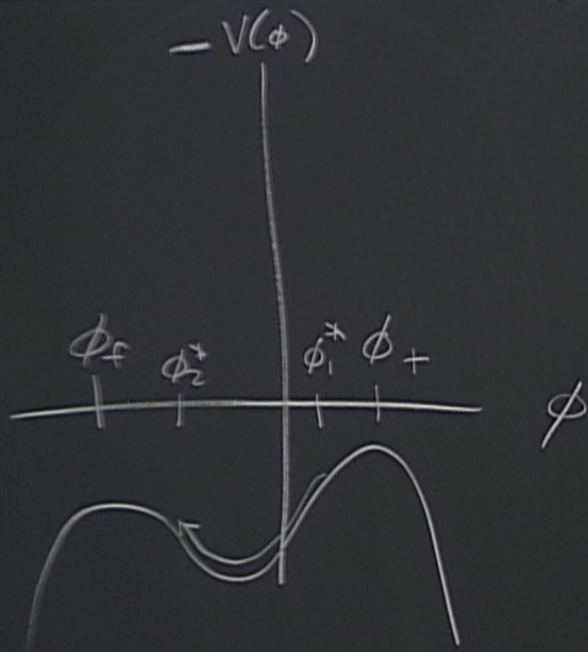
$$\ddot{\rho} = -\frac{\rho}{3M_P^2}(\dot{\phi}^2 + V)$$





$$\ddot{\phi} = -\frac{\rho}{3M_P^2}(\dot{\phi}^2 + V)$$





$$\frac{\Gamma}{\text{vol}} = A e^{-B/\hbar}$$

$$B = S_E[\phi_I] - S_E[\phi_f]$$

↑
need to subtract off background
solution

$$S_E[\phi_f] = -24\pi^2 \frac{M_p^4}{V(\phi_f)}$$

$$S_E[\phi_I] < 0$$

$$\frac{\Gamma}{V} < 1 \quad \text{for approximation to be valid}$$

$$|S_E[\phi_f]| > |S_E[\phi_I]|$$

$$S_E[\phi_E] < 0$$

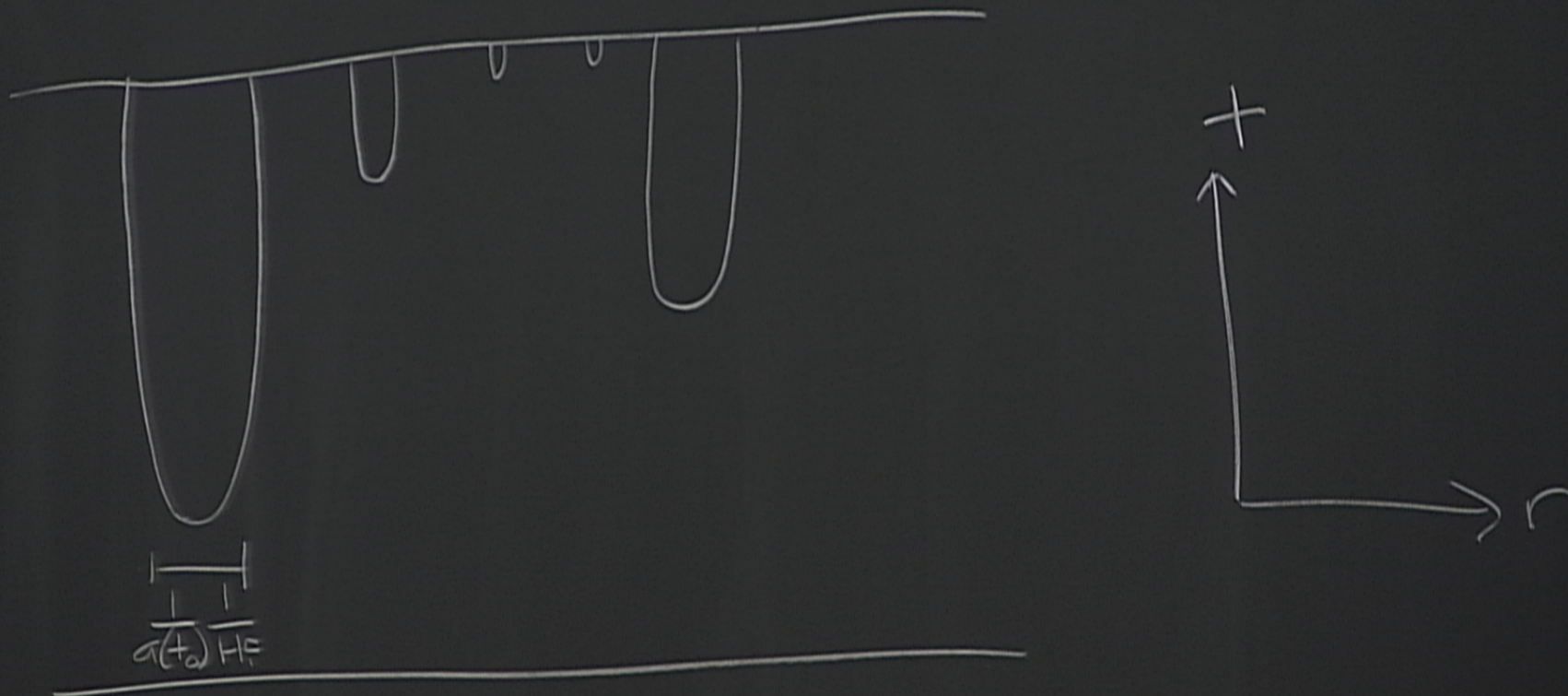
What do bubbles look like after nucleation?

flat slicing: $ds^2 = -dt^2 + e^{2H_F t} (dr^2 + r^2 d\Omega^2)$

$$\partial_t R_{+0}(t) \approx \frac{1}{a(t)} \approx e^{-H_F t}$$

↑
comoving position of bubble
wall that nucleates at t_0
centered at $r=0$

$$\begin{aligned} R_{+0}(t) &\approx \int_{t_0}^t e^{-H_F t'} dt' \\ &\approx \frac{1}{H_F} \left(e^{-H_F t_0} - e^{-H_F t} \right) \\ &\approx \frac{1}{H_F} e^{-H_F t_0} \end{aligned}$$



When is inflation eternal?

F_f = fraction of comoving volume in false vacuum

$$\partial_t F_f = - \left(\frac{\# \text{ bubbles}}{4\text{-vol}} \right) (\text{vol in } F) \left(\frac{\text{comoving vol}}{\text{bubble}} \right) \left(\frac{1}{\text{total comoving}} \right)$$

$$= - \left(\frac{\Gamma}{\text{vol}} \right) \left(F_f H_F^{-3} e^{3H_F t} \right) \left(\frac{4\pi}{3} H_F^{-3} e^{-3H_F t} \right) \left(\frac{1}{H_F^{-3}} \right)$$

$$= - \frac{4\pi}{3} \left(\frac{\Gamma}{\text{vol}} \right) H_F^{-3} F_f = - \chi_{TF} F_f$$

$$F_f = e^{-\chi_{TF} + 3H_F +}$$

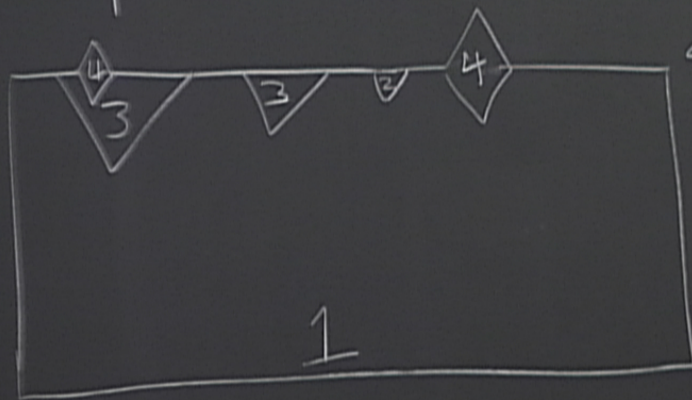
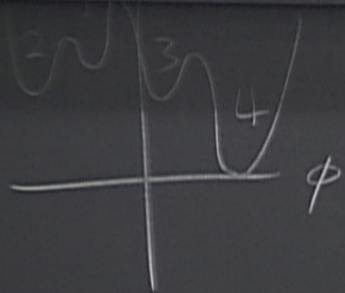
phys. vol.

$$V_F \propto F_f e^{(3H_F - \chi_{TF}) +}$$

$$\propto e$$

$$H_F^4 \approx \frac{\Gamma}{\text{vol}} \Leftrightarrow EI$$

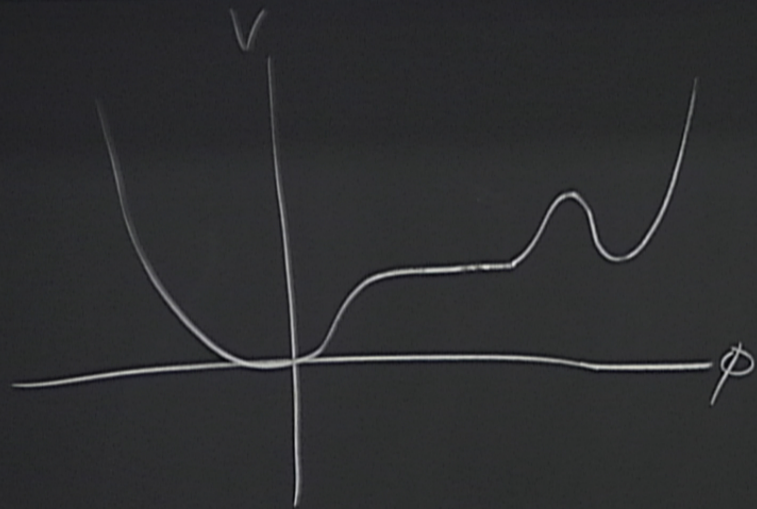
$$S(V_0) / H_f t_f \sim \lambda_{TF} t_f$$



fractal distribution

symmetry of bubble $\rightarrow$ inside of each bubble
is an ∞ open FRW universe

∞ # bubbles as $t \rightarrow \infty$



need SR after nucleation in order to

need SR after nucleation in order to dilute curvature

$$\{1, 2, 3, 4, 5, 6, \dots\}$$

$$\frac{P_{\text{odd}}(n)}{P_{\text{even}}(n)} = \frac{\lfloor \frac{n+1}{2} \rfloor}{\lfloor \frac{n}{2} \rfloor}$$

$$\frac{P_A}{P_B} = \lim_{n \rightarrow \infty} \frac{\lfloor \frac{n+1}{2} \rfloor}{\lfloor \frac{n}{2} \rfloor} = 1$$

$$\{1, 3, 2, 5, 7, 4, \dots\}$$

$$\frac{P_{\text{odd}}(n)}{P_{\text{even}}(n)} = \frac{\lfloor \frac{2n+2}{3} \rfloor}{\lfloor \frac{n}{3} \rfloor}$$

$$\frac{P_A}{P_B} = \lim_{n \rightarrow \infty} \frac{\lfloor \frac{2n+2}{3} \rfloor}{\lfloor \frac{n}{3} \rfloor} = 2$$

Example: proper time cutoff

Begin with a finite initial surface at $t=0$
count all events that occur before t_c , $t_c \rightarrow \infty$

$$H_{EI}^{-1} \sim 10^{-40} \text{ s}$$

- Obs. evidence for EI?
 - bubble collisions
- conditions for EI satisfied?
 - support SEI?
 - long lived vacua for FVEI?
- unique or preferred measure?