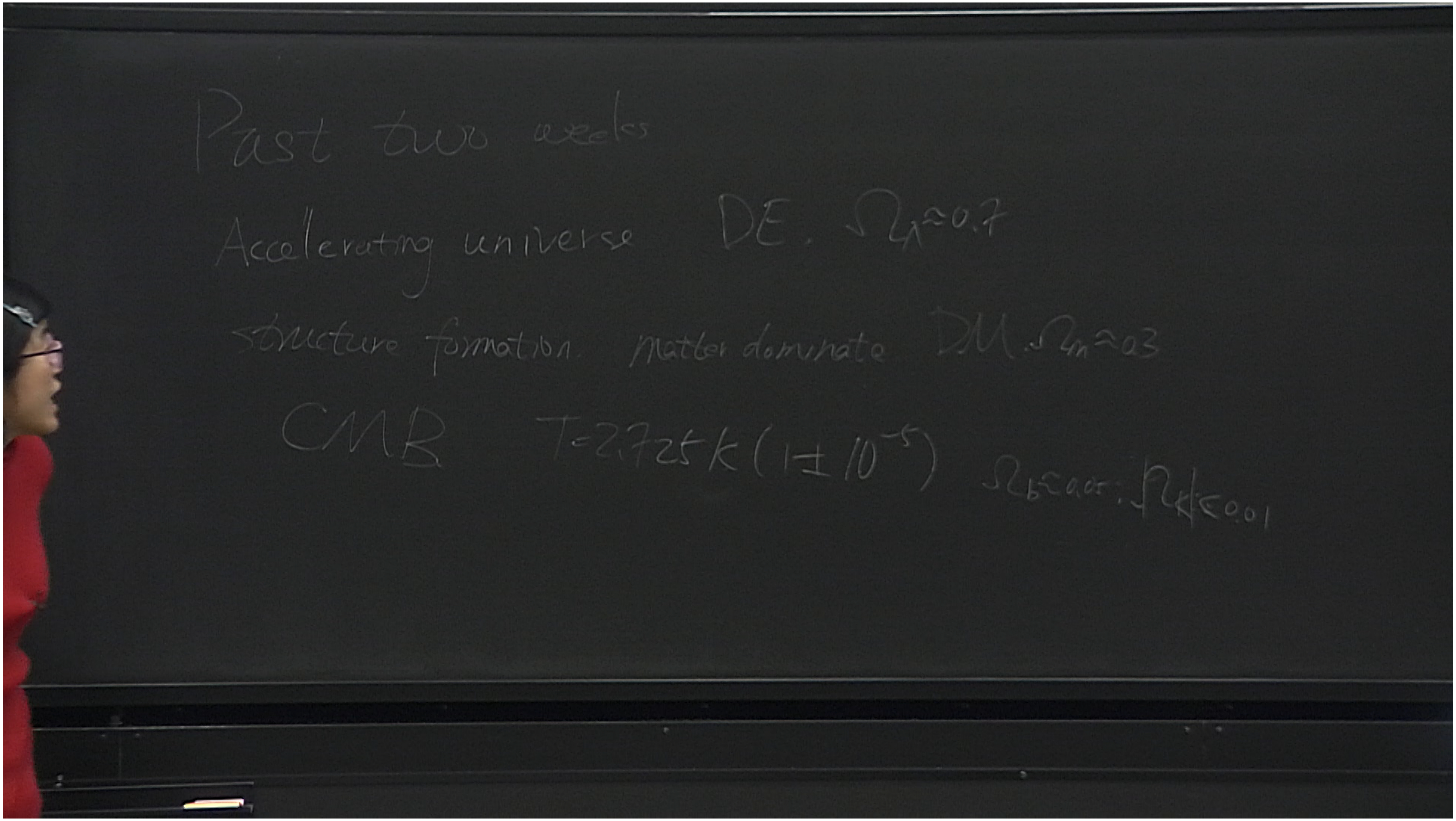
Title: PSI 2018/2019 - Cosmology Review - Lecture 11

Date: Jan 21, 2019 09:00 AM

URL: http://pirsa.org/19010012

Abstract:


Past two weeks
Accelerating universe DE. $\Omega_\Lambda \simeq 0.7$
structure formation matter dominate DM. $\Omega_m \simeq 0.3$
CMB $T = 2.725K(1 \pm 10^{-5})$ $\Omega_b \simeq 0.05$; $|\Omega_k| \lesssim 0.01$

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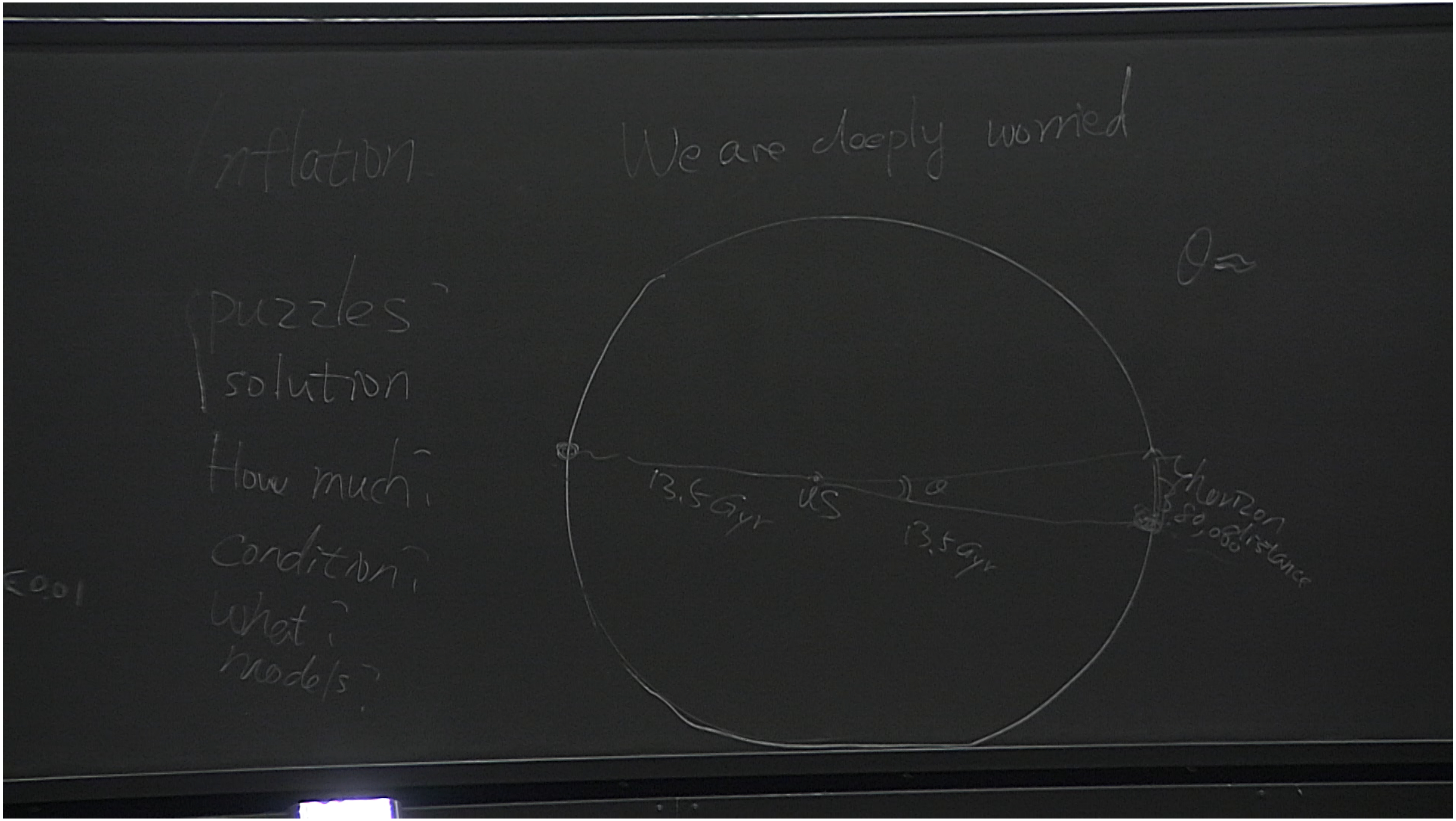
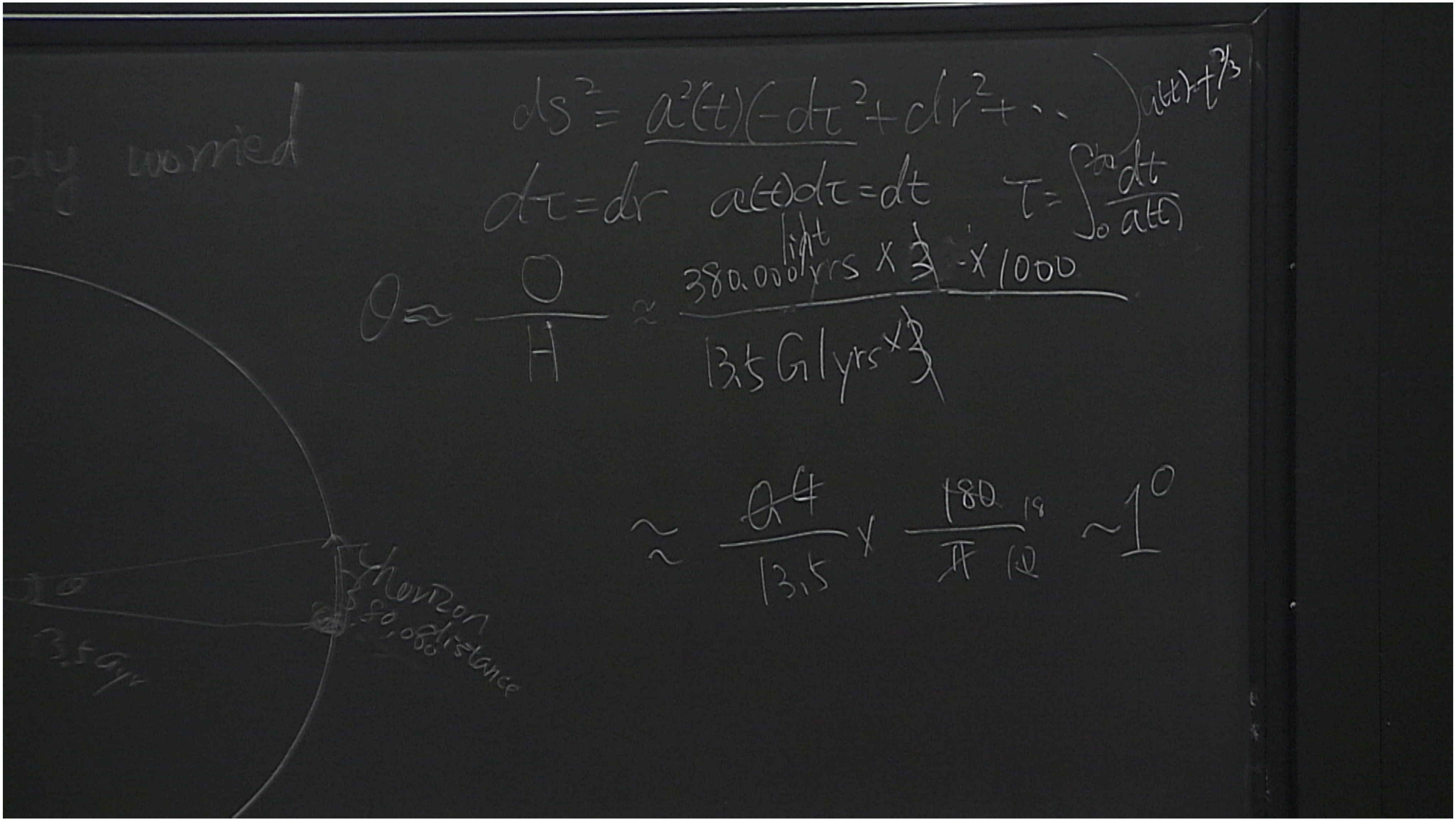
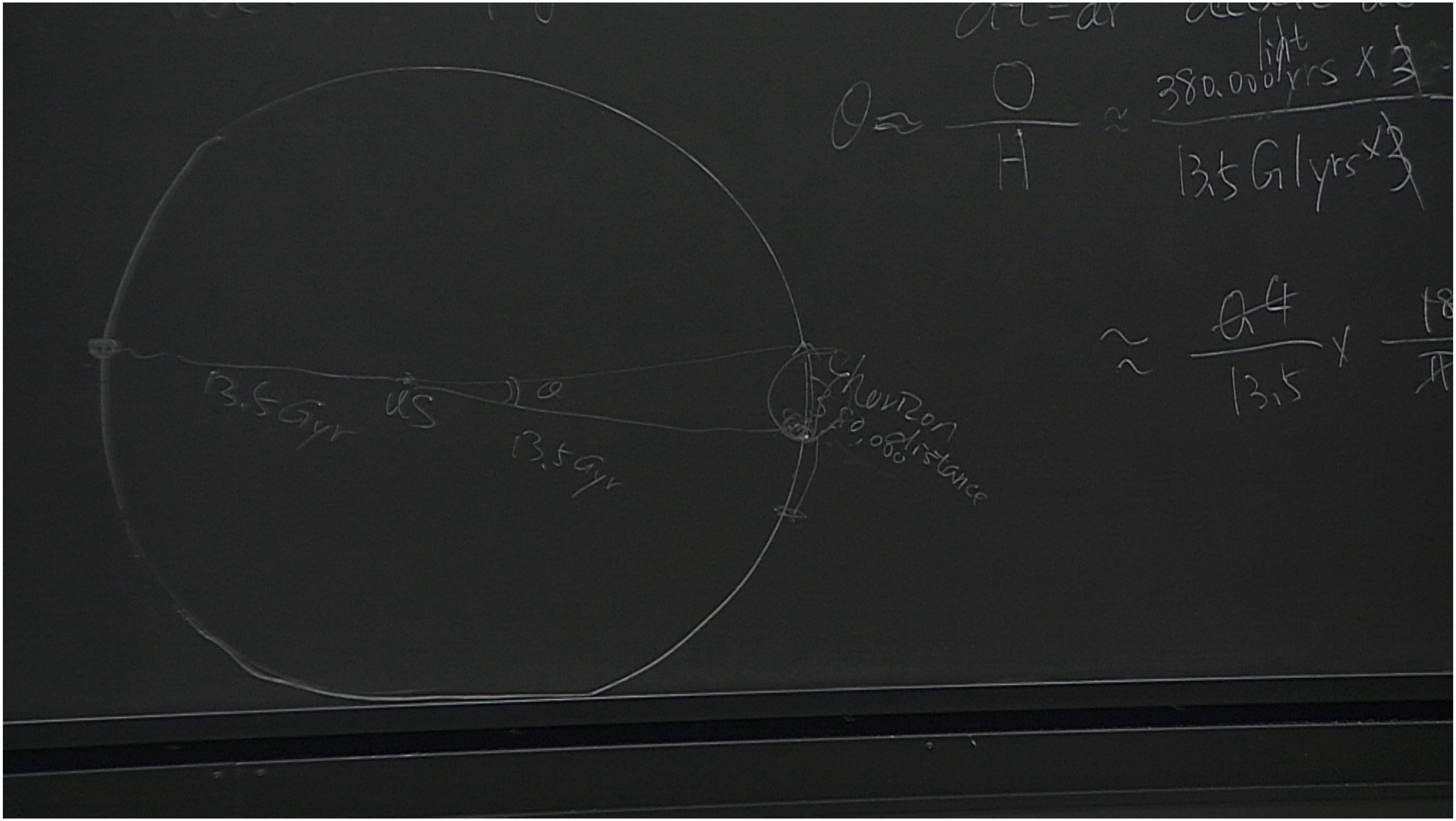
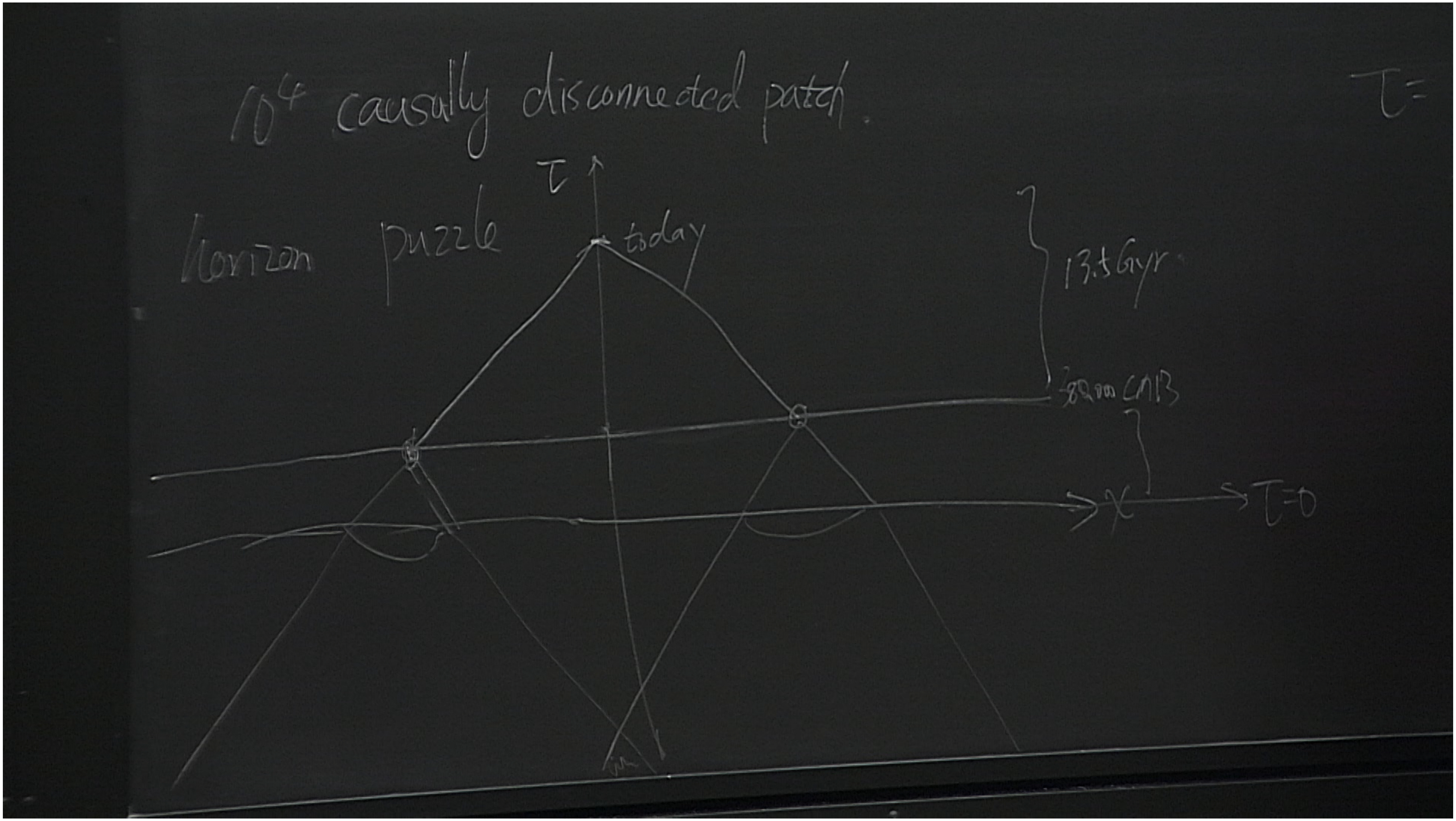

Inflation
We are deeply worried
puzzles?
solution
How much?
Condition?
What?
models?
13.5 Gyr
us
13.5 Gyr
horizon


worried
ds² = a²(t)(-dτ² + dr² + . .)
a(t) ~ t^(2/3)
dτ = dr
a(t)dτ = dt
τ = ∫₀^t₀ dt / a(t)
θ ≈ O / H ≈ 380,000 light yrs × 3 × 1000 / 13.5 G lyrs × 3
≈ 0.4 / 13.5 × 180 / π ~ 1°
horizon
80,000 distance
13.5 Gyr



θ ≈ O/H ≈ 380,000 light yrs x 3 / 13.5 G lyrs x 3
≈ 0.4/13.5 x 18
13.5 Gyr
us
θ
13.5 Gyr
horizon
380,000 distance


10^4 causally disconnected patch.
τ=
horizon puzzle
τ
today
13.7 Gyr
CMB
x
τ=0

$$\Delta\tau = \int_{\tau_i}^{\tau} \frac{dt}{a(t)} = \int_{\tau_i}^{\tau} t^{-\frac{2}{3(w+1)}}\, dt = \frac{1}{1-\frac{2}{3(w+1)}}\, t^{1-\frac{2}{3(w+1)}} \Big|_{\tau_i}^{\tau}$$

$$a(t) = t^{\frac{2}{3(w+1)}}$$

$$1-\frac{2}{3(w+1)} = \frac{3w+1}{3(w+1)}$$

$$\tau_i = \frac{3(w+1)}{3w+1}\, t_i^{\frac{3w+1}{3(w+1)}}$$

$t_i \to 0$ $\quad \tau_i \to 0$

normal $w = 0, \frac{1}{3}$

$-1 < w < -\frac{1}{3}$

$\to \tau = 0$

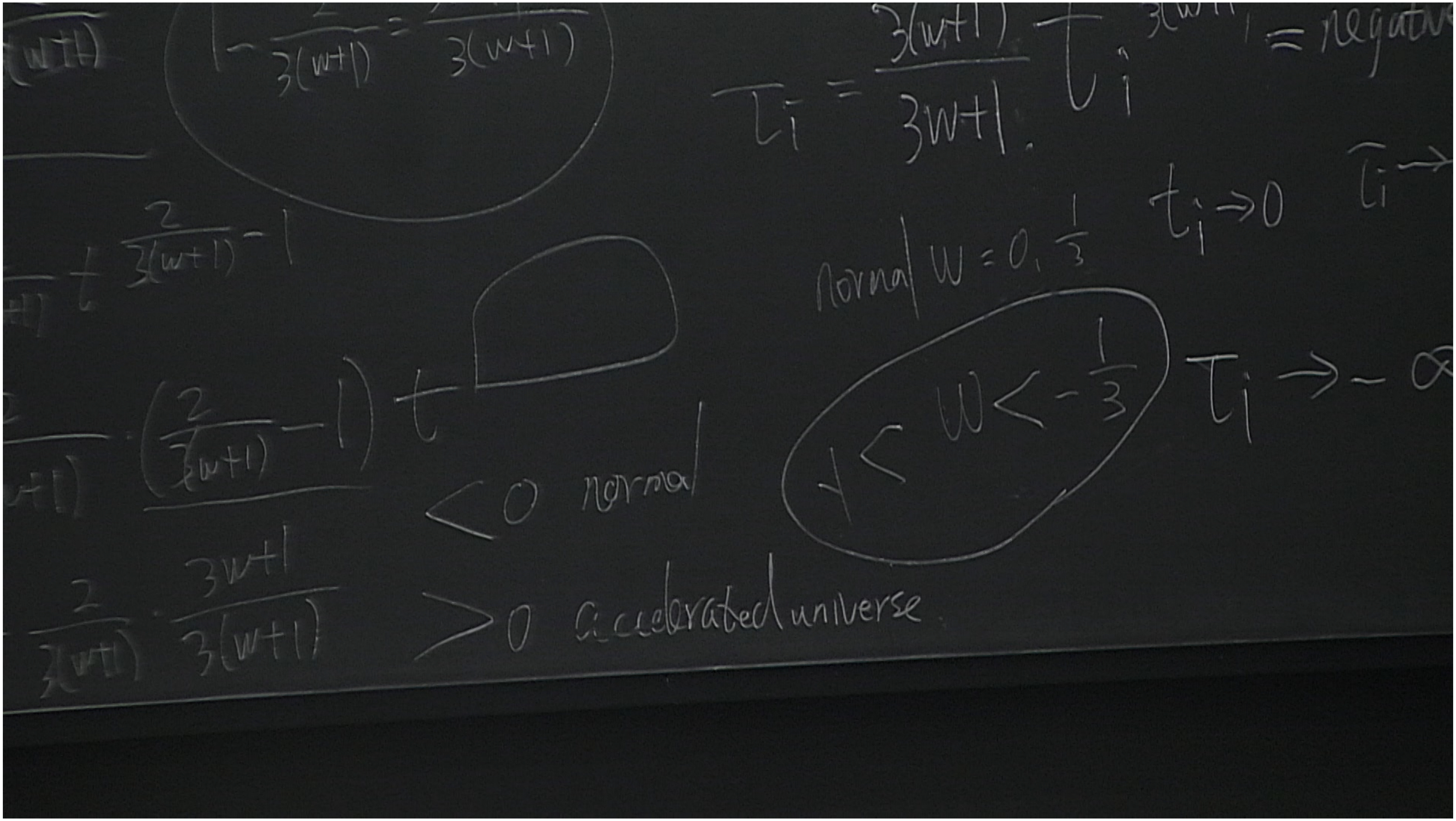
$$\ldots dt = \frac{1}{1-\frac{2}{3(w+1)}}\, t^{1-\frac{2}{3(w+1)}} \Big|_{\tau_i}^{\tau}$$

$$\frac{3w+1}{3(w+1)}$$

$$\tau_i = \frac{3(w+1)}{3w+1}\, t_i^{\frac{3w+1}{3(w+1)}} = \text{negative} \times 0^{\text{negative}}.$$

normal $w = 0, \frac{1}{3}$ $\quad t_i \to 0 \quad \tau_i \to 0$

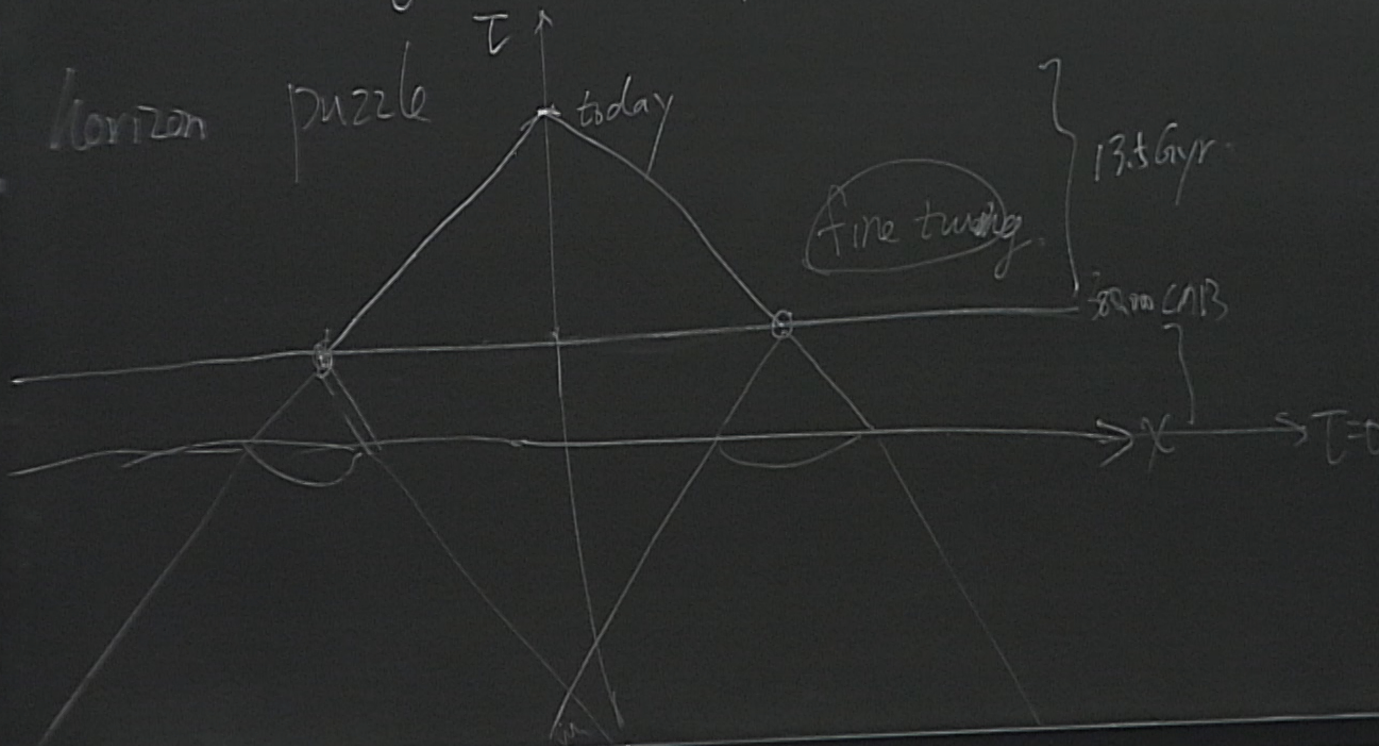
$-1 < w < -\frac{1}{3}$ $\quad \tau_i \to -\infty$



normal w = 0, 1/3
t_i → 0
τ_i → − ∞
−1 < w < −1/3
< 0 normal
> 0 accelerated universe

10^4 causally disconnected patch.

horizon puzzle



$$\Delta\tau = \int_{\tau_i}^{\tau} \frac{dt}{a(t)} = \int_{\tau_i}^{\tau} \ldots$$

$$a(t) = t^{\frac{2}{3(w+1)}}$$

$$\dot a(t) = \frac{2}{3(w+1)}\, t^{\frac{2}{3(w+1)} \ldots}$$

$$\ddot a(t) = \frac{2}{3(w+1)} \cdot \left(\frac{2}{3(w+\ldots}\right.$$

$$= -\frac{2}{3(w+1)} \cdot \frac{3\ldots}{3(\ldots}$$

Flatness puzzle.

$$H^2 = \frac{\rho}{3M_{pl}^2} - \frac{k}{a^2}$$

$$\left|\frac{\rho}{\rho_{crit}} - 1\right| = \frac{|k|}{a^2H^2} = \frac{|k|}{\dot{a}^2} = \frac{1}{\dot{a}^2}$$

$$\underline{H^2 \cdot 3M_{pl}^2 = \rho_{crit}}$$

normal $\ddot{a} < 0$ $\dot{a} \searrow$ $|\Omega_k$ nonflatness$| \nearrow$ $\simeq 0.01$

$|\Omega_k|_{BBN} \sim 10^{-31}$

accelerating $\dot{a} \nearrow$ $|\Omega_k| \downarrow$

it is natural not to observe curvature.

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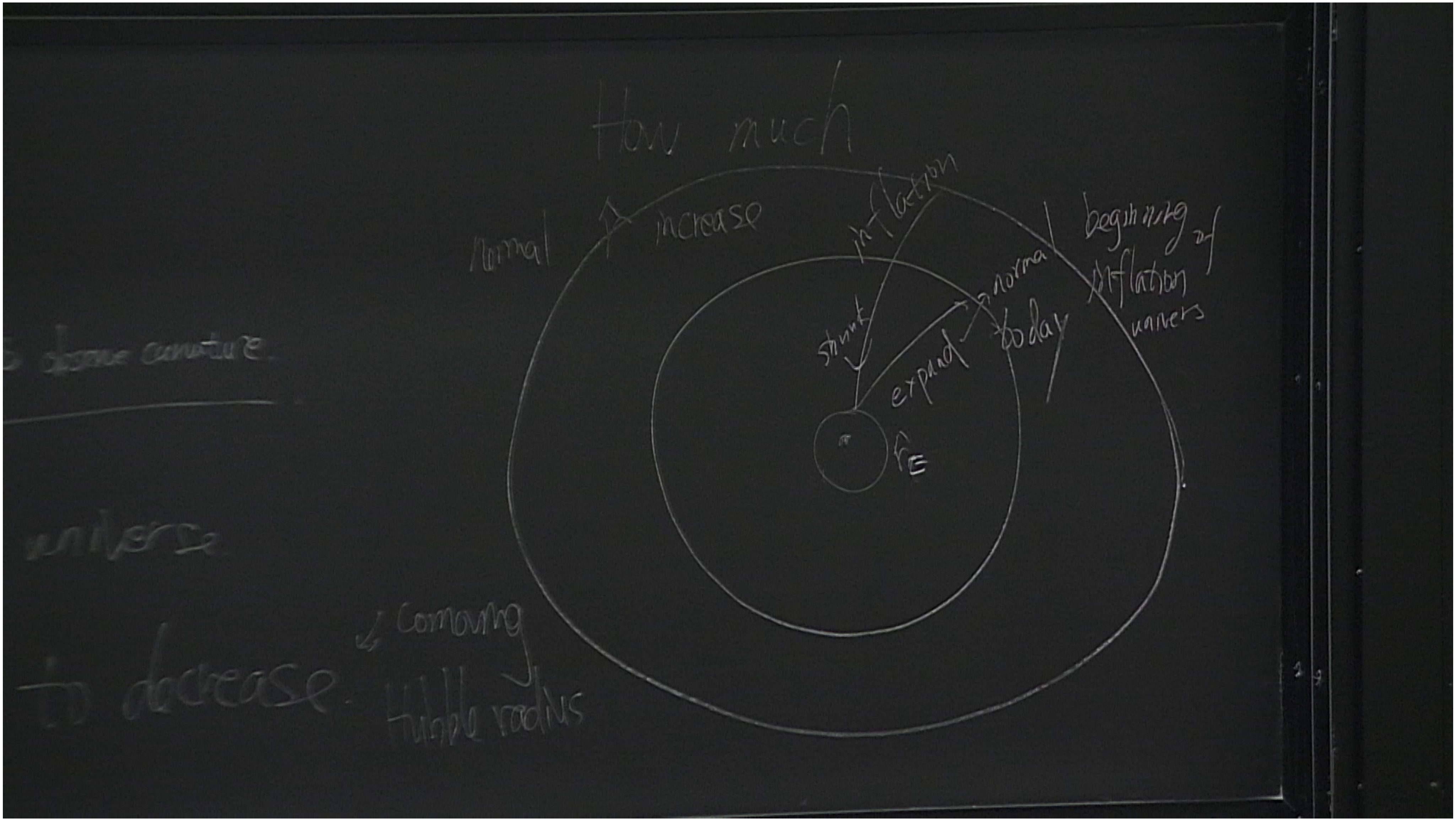
solution: accelerating universe

$$r = \frac{1}{\dot{a}} = \frac{1}{aH}$$ to decrease. comoving Hubble radius



How much
normal
increase
inflation
beginning of inflation univers
normal
shrink
expand
today
universe
to decrease
Comoving Hubble radius

$$\hat{r}_I > \hat{r}_{today}$$

$$a_I H_I < a_0 H_0 \qquad H \sim \frac{T^2}{M_{pl}} \sim \frac{1}{a^2}$$

$$\frac{\hat{r}_E}{\hat{r}_0} = \frac{a_0 H_0}{a_E H_E} = \frac{a_0\, a_E^2}{a_E\, a_0^2} = \frac{a_E}{a_0} \sim \frac{T_0}{T_E} \sim \frac{10^{-4}\,\mathrm{eV}}{10^{15}\,\mathrm{GeV}} \sim 10^{-28} \sim e^{-64}$$

We need 30~60 e-folds of inflation.

$$N = \ln \frac{a}{a_E}$$

$$\epsilon = -\frac{\dot{H}}{H^2} = \frac{dH}{-dt\,H \cdot H} = \frac{dH}{-dN\,H} \qquad H = \frac{\dot{a}}{a}$$

$$\epsilon = -\frac{dH}{dN\,H} \qquad -1 < w < -\frac{1}{3}$$

$$< 0$$

$$\ll 1 \qquad \eta = \frac{d\epsilon}{dN\,\epsilon} \ll 1$$