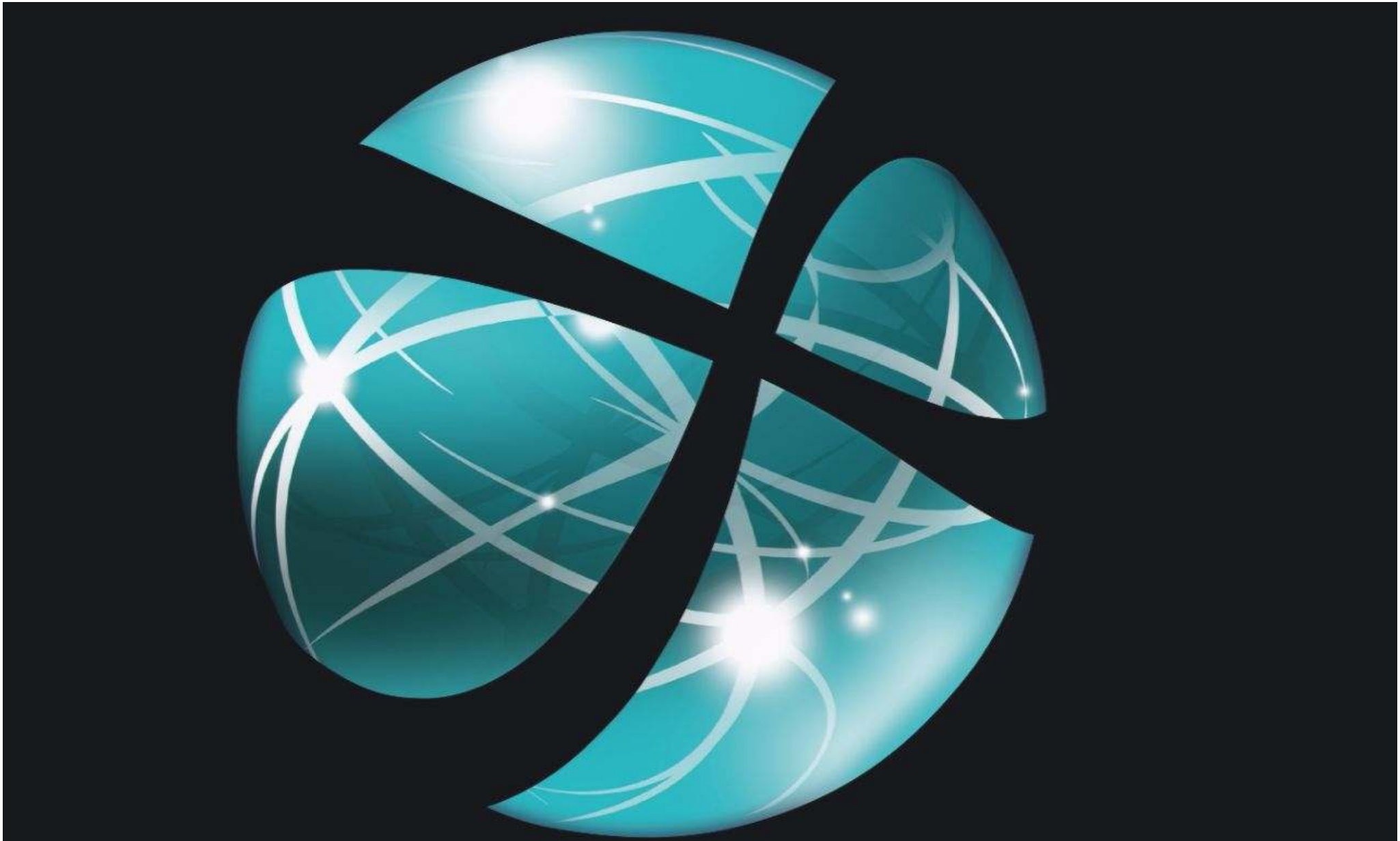
Title: Cosmology - Review (PHYS 621) - Lecture 15

Date: Dec 18, 2009 10:00 AM

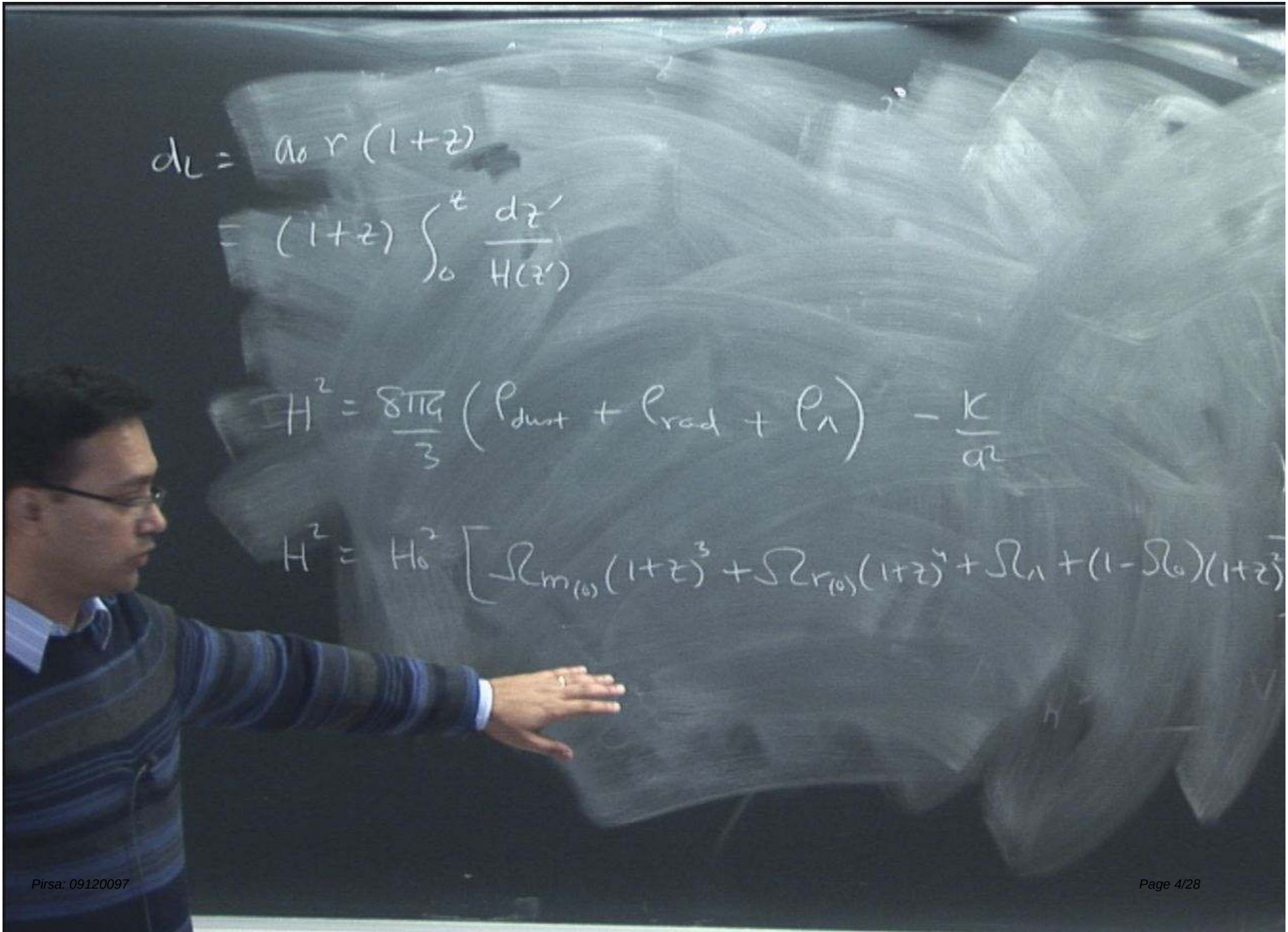
URL: http://pirsa.org/09120097

Abstract:


perimeter scholars
international

$$d_L = a_0 r (1+z)$$

$$= (1+z) \int_0^z \frac{dz'}{H(z')}$$


$d_L = a_0 r (1+z)$
$= (1+z) \int_0^t \frac{dz'}{H(z')}$
$H^2 = \frac{8\pi G}{3} (\rho_{dust} + \rho_{rad} + \rho_\Lambda) - \frac{K}{a^2}$
$H^2 = H_0^2 [\Omega_{m(0)}(1+z)^3 + \Omega_{r(0)}(1+z)^4 + \Omega_\Lambda + (1-\Omega_0)(1+z)^2$

$$d_L = a_0 r (1+z)$$

$$= (1+z) \int_0^z \frac{dz'}{H(z')}$$

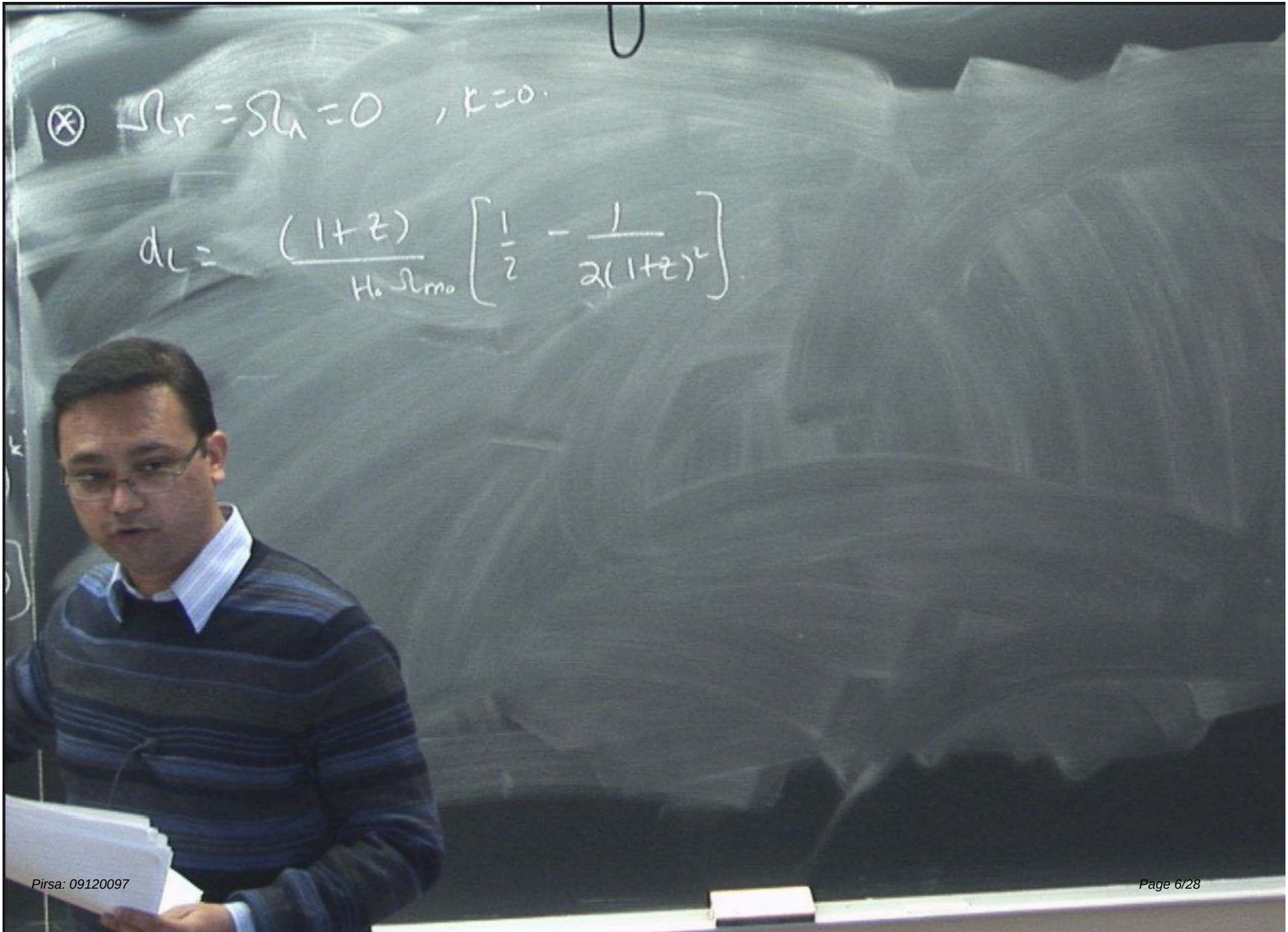
$$\Omega = \frac{\rho}{\rho_c}$$

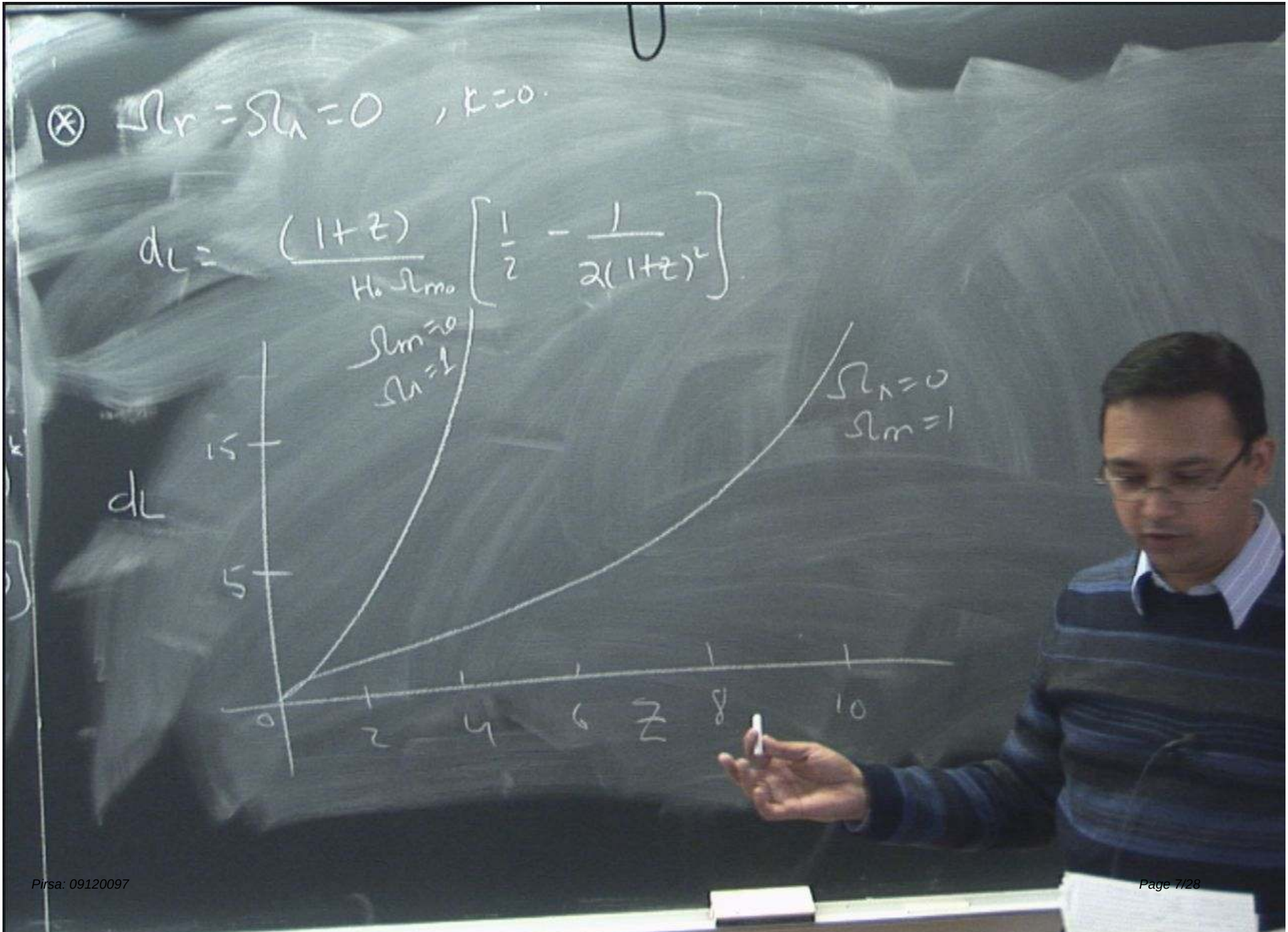
$$H^2 = \frac{8\pi G}{3}\left(\rho_{dust} + \rho_{rad} + \rho_\Lambda\right) - \frac{K}{a^2}$$

$$H^2 = H_0^2 \left[\Omega_{m(0)}(1+z)^3 + \Omega_{r(0)}(1+z)^4 + \Omega_\Lambda + (1-\Omega_0)(1+z)^2\right]$$

(*) $K=0$; $\Omega_\Lambda = 1$, $\Omega_r = \Omega_{dust} = 0$, $\Omega_0 = 1$

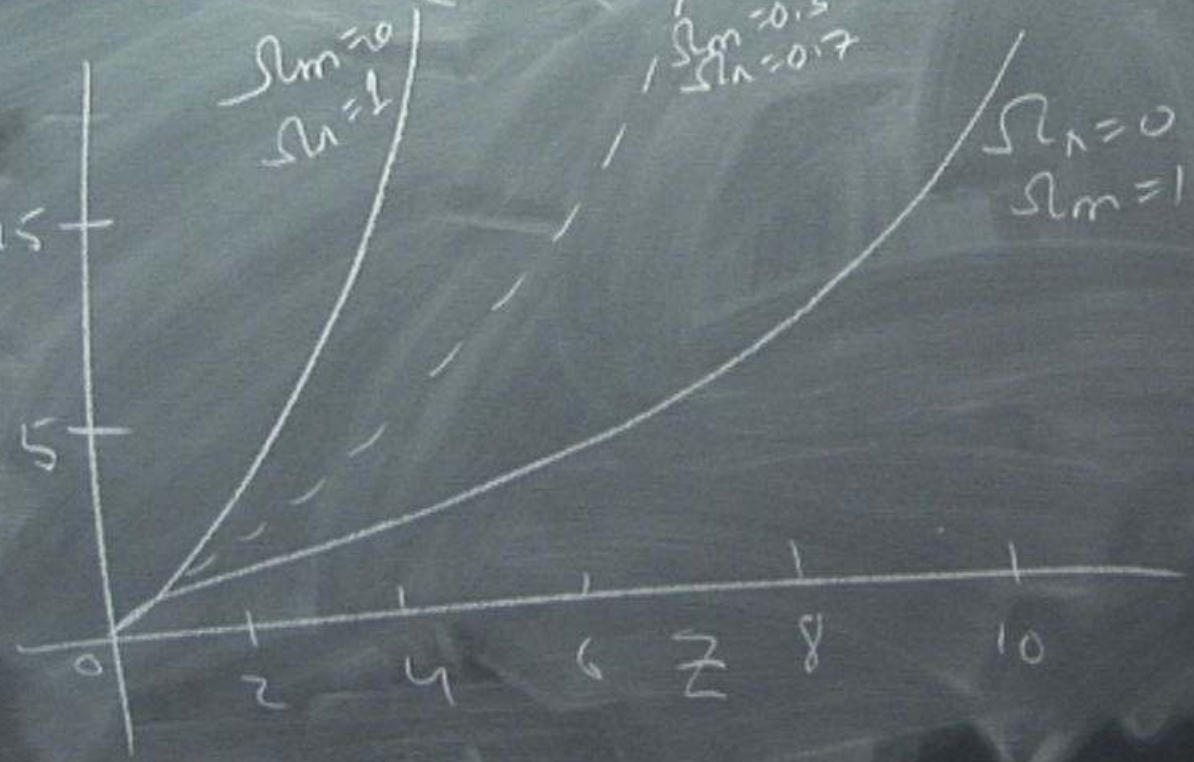
$$d_L = (1+z)\int_0^z \frac{dz'}{H_0\sqrt{\Omega_\Lambda}} = \frac{(z^2+z)}{H_0}$$


⊗ $\Omega_r = \Omega_\Lambda = 0$, $k = 0$.
$d_L = \frac{(1+z)}{H_0 \Omega_{m_0}} \left[\frac{1}{2} - \frac{1}{2(1+z)^2} \right]$


⊛ $\Omega_r = \Omega_\Lambda = 0$, $k = 0$.
$d_L = \frac{(1+z)}{H_0 \Omega_{m_0}} \left[\frac{1}{2} - \frac{1}{2(1+z)^2} \right]$
$\Omega_m = 0$
$\Omega_\Lambda = 1$
$\Omega_\Lambda = 0$
$\Omega_m = 1$
d_L
15
5
0
2
4
6
8
10

⊛ $\Omega_r = \Omega_\Lambda = 0$, $k = 0$.

$$d_L = \frac{(1+z)}{H_0 \Omega_{m_0}} \left[\frac{1}{2} - \frac{1}{2(1+z)^2} \right]$$



$$l = \frac{L}{4\pi d_L^2}$$

$$H^2 = H_0^2 \left[\Omega_{m(0)}(1+z)^3 + \Omega_{r(0)}(1+z)^4 + \Omega_\Lambda + (1-\Omega_0)(1+z)^2 \right]$$

(*) $k=0$; $\Omega_\Lambda = 1$, $\Omega_r = \Omega_{dust} = 0$, $\Omega_0 = 1$

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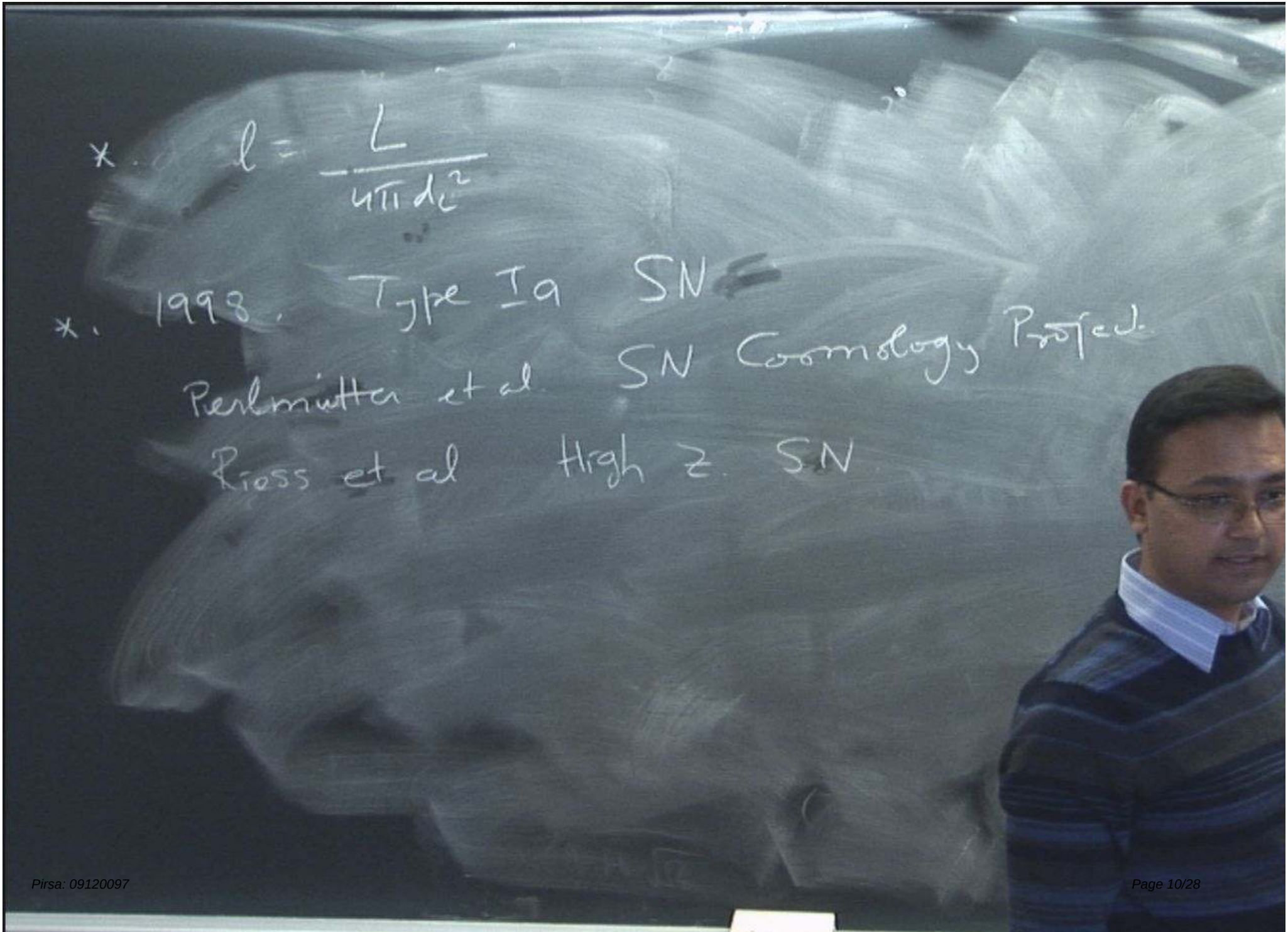
* $l = \frac{L}{4\pi d_L^2}$
* 1998. Type Ia SN
Perlmutter et al SN Cosmology Project
Riess et al High z SN

$$l = \frac{L}{4\pi d_L^2}$$

$$\textcircled{*} \quad q = -\frac{\ddot{a}}{aH^2}$$

$k = 0.$

$$q(t) = \Omega_{r(t)} + \frac{1}{2}\Omega_{m(t)} - \Omega_\Lambda$$

$$\simeq \frac{\Omega_{m(0)}}{2a^3} - \Omega_\Lambda = \frac{1}{2}\Omega_{m(0)}(1+z)^3 - \Omega_\Lambda$$

$$l = \frac{L}{4\pi d_L^2}$$

$$q = -\frac{\ddot{a}}{aH^2}$$

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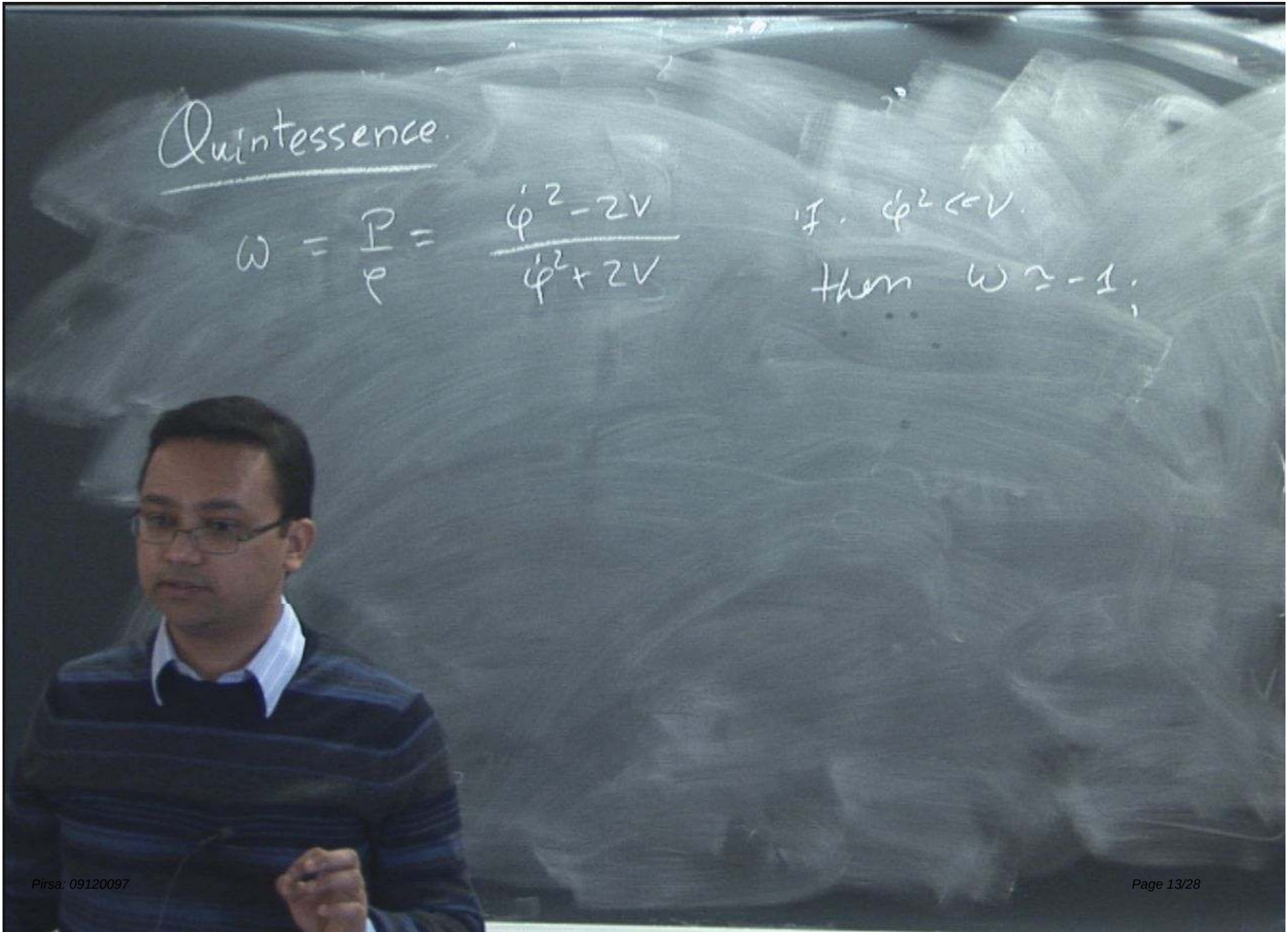
$$\simeq \frac{\Omega_{m(0)}}{2a^3} - \Omega_\Lambda = \frac{1}{2}\Omega_{m(0)}(1+z)^3 - \Omega_\Lambda$$

$$(1+z)^3 = \frac{2\Omega_\Lambda}{\Omega_{m(0)}} \Rightarrow 1+z = 1.67 \quad \boxed{z = 0.67}$$


Quintessence.
$\omega = \frac{P}{\rho} = \frac{\dot{\varphi}^2 - 2V}{\dot{\varphi}^2 + 2V}$
If. $\dot{\varphi}^2 \ll V$.
then $\omega \simeq -1$.

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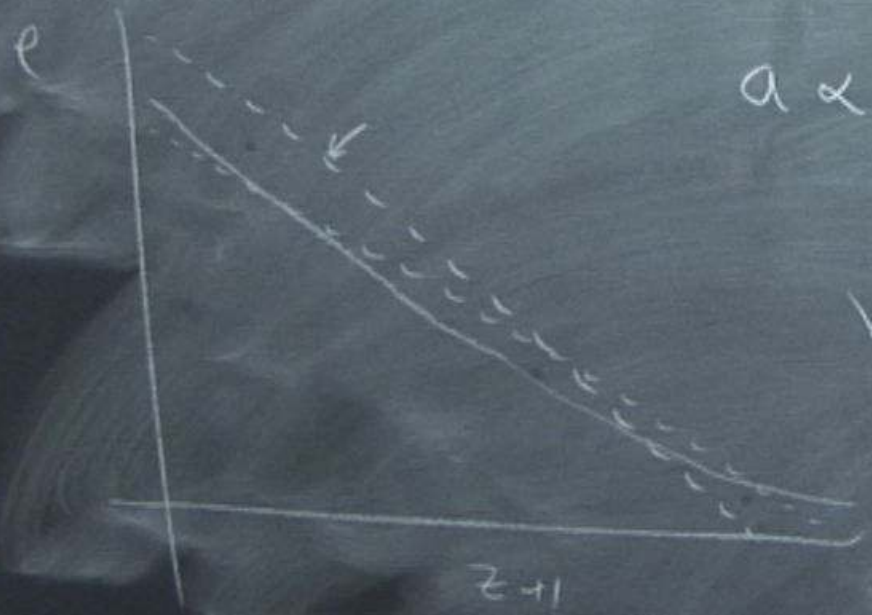

$$a \propto t^p \qquad \ddot a > 0$$

$$p > 1$$

$$V = \frac{3H^2}{8\pi G}\left(1 + \frac{\dot H}{3H^2}\right)$$

$$\dot H = -4\pi G\,\dot\varphi^2$$

$$\Phi = \int dt \left(-\frac{\dot H}{4\pi G}\right)^{1/2}$$

$$V = V_0 \exp\left(-\sqrt{\frac{k\pi}{p}}\,\frac{\varphi}{m_{pl}}\right)$$

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$$V(\varphi) = \frac{V_0}{\varphi^{\alpha}}$$

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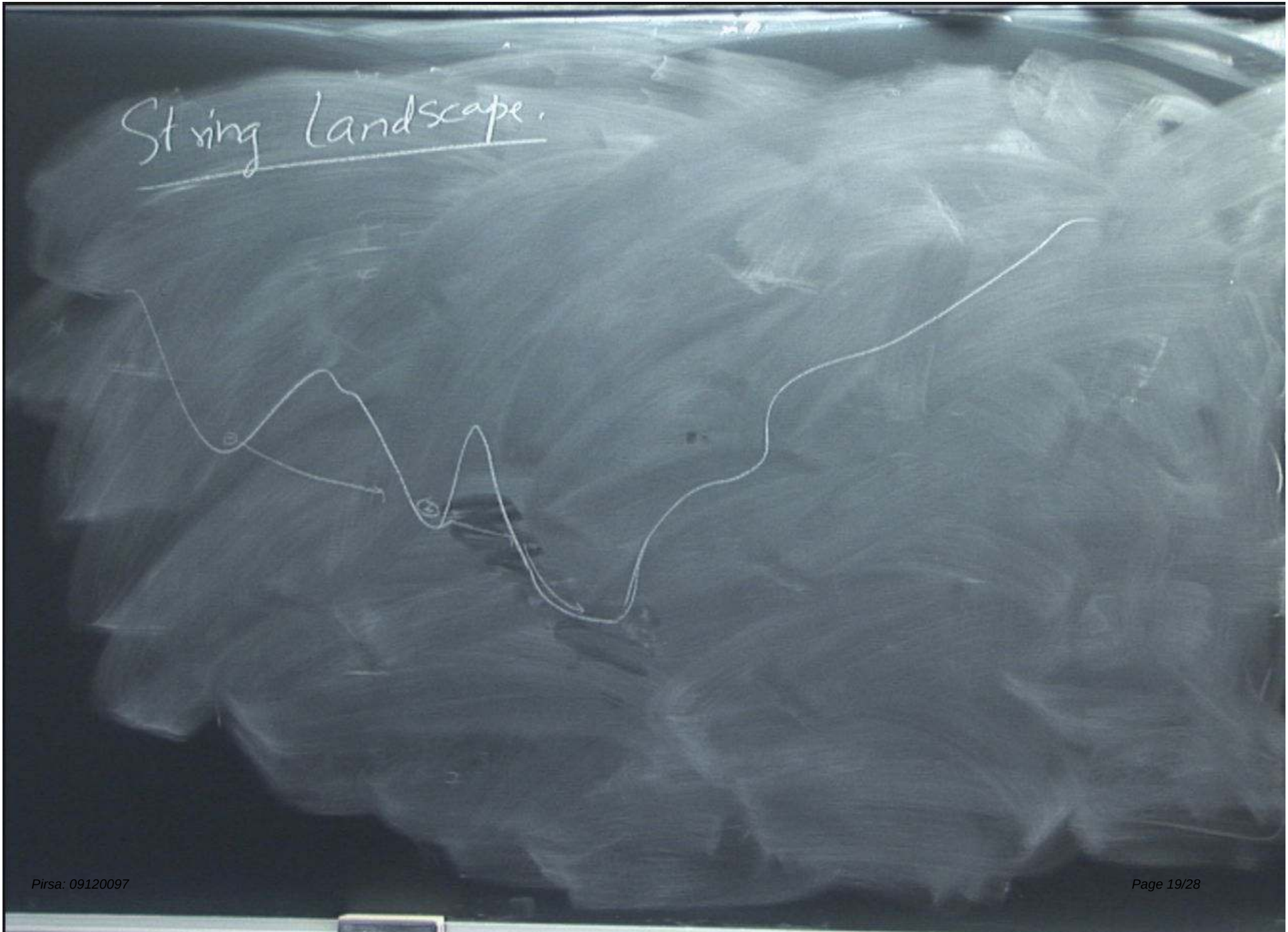
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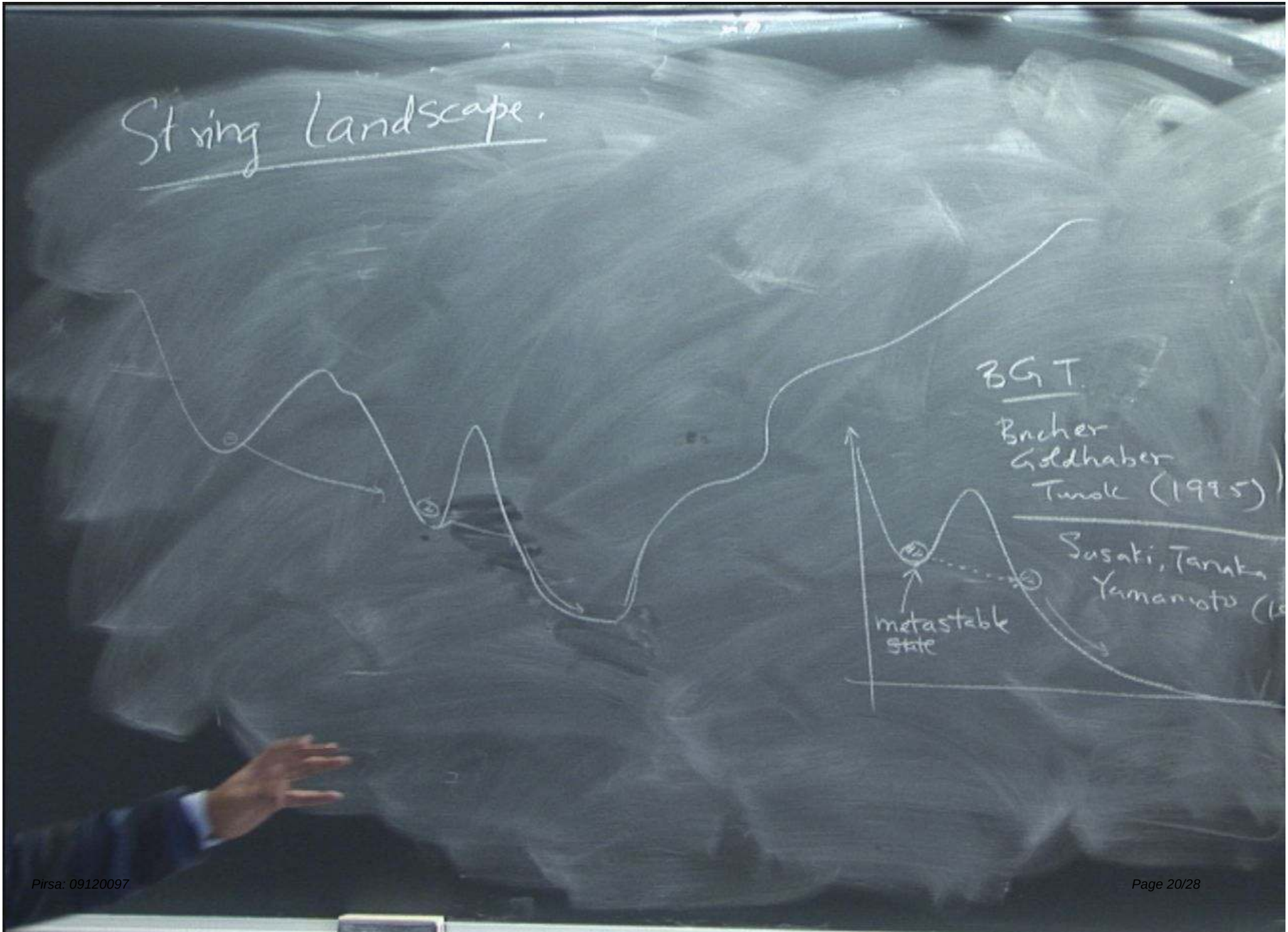
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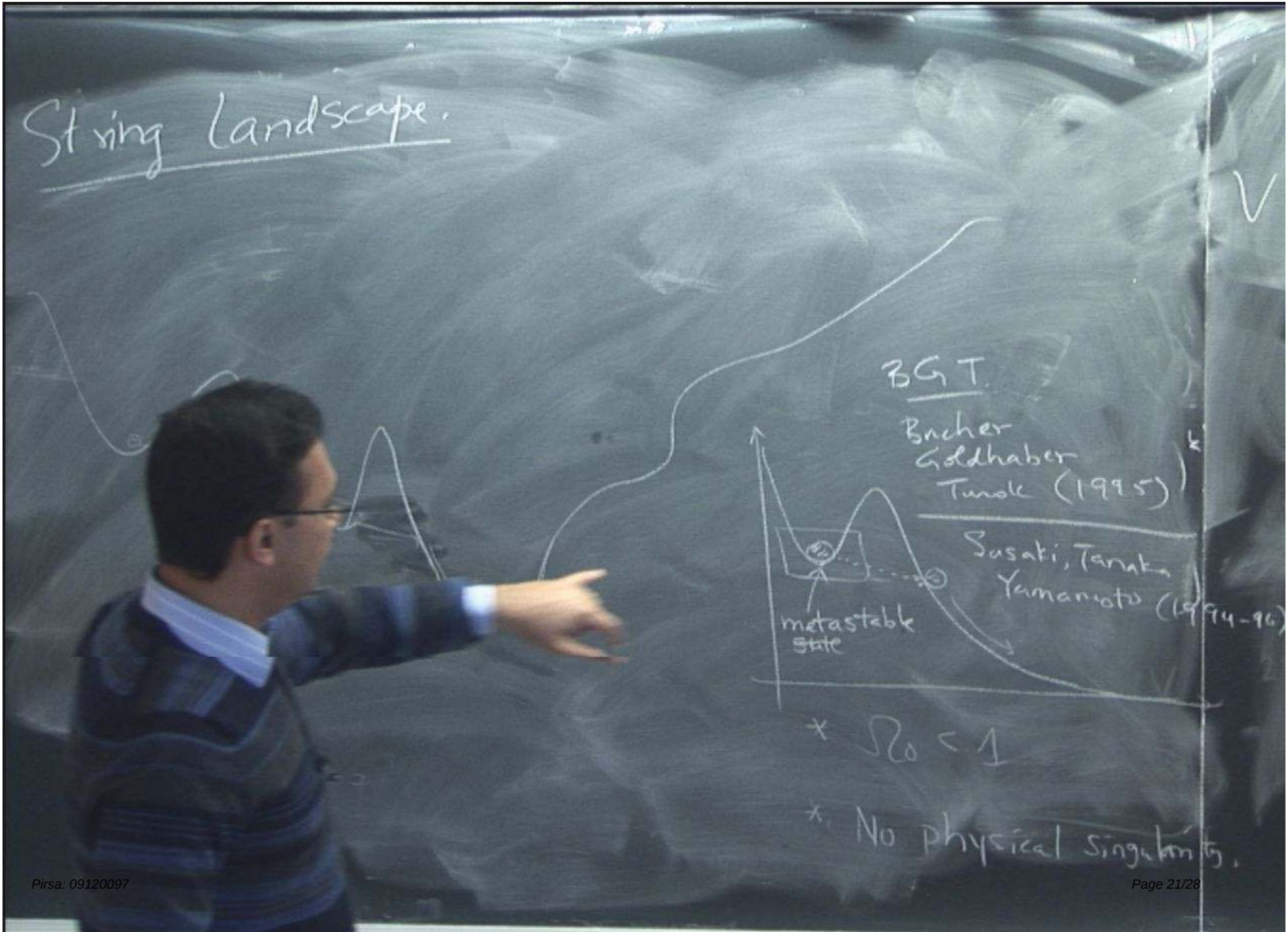
BGT
Bucher
Goldhaber
Turok (1995)
Susaki, Tanaka
Yamamoto
metastable
state


String landscape.
V
BGT
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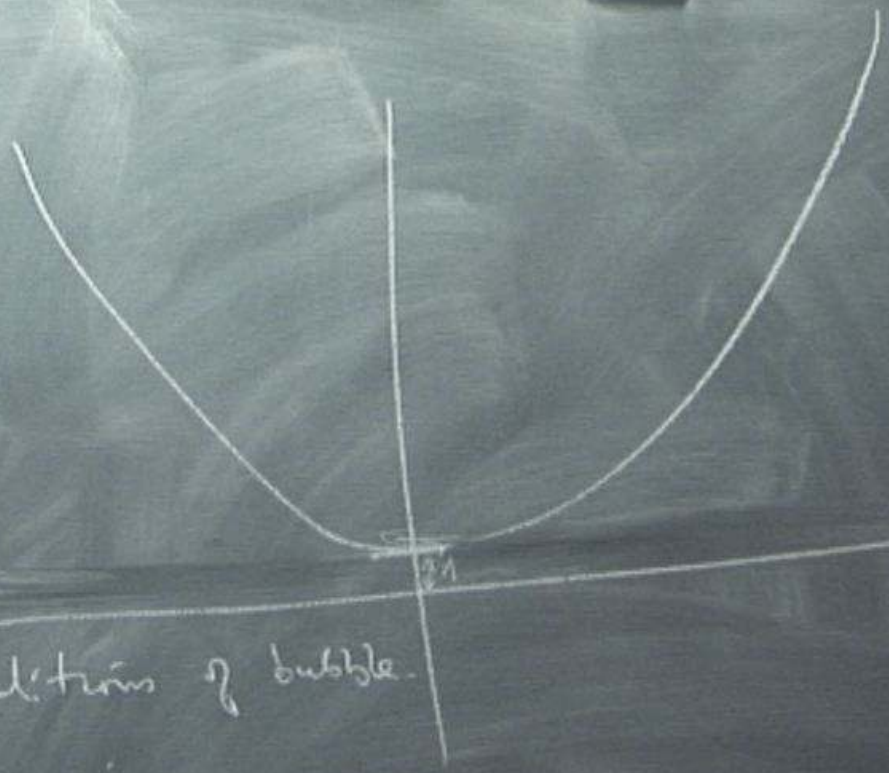
Susaki, Tanaka
Yamamoto (1994-96)
metastable
state
* $\Omega_0 < 1$
*. No physical singularity.

$$V = V_0 \exp\left(-\sqrt{\frac{8\pi}{p}}\,\frac{\varphi}{m_{pl}}\right)$$

$$V(\varphi) = \frac{V_0}{\varphi^{\alpha}}$$



* Initial condition of bubble.

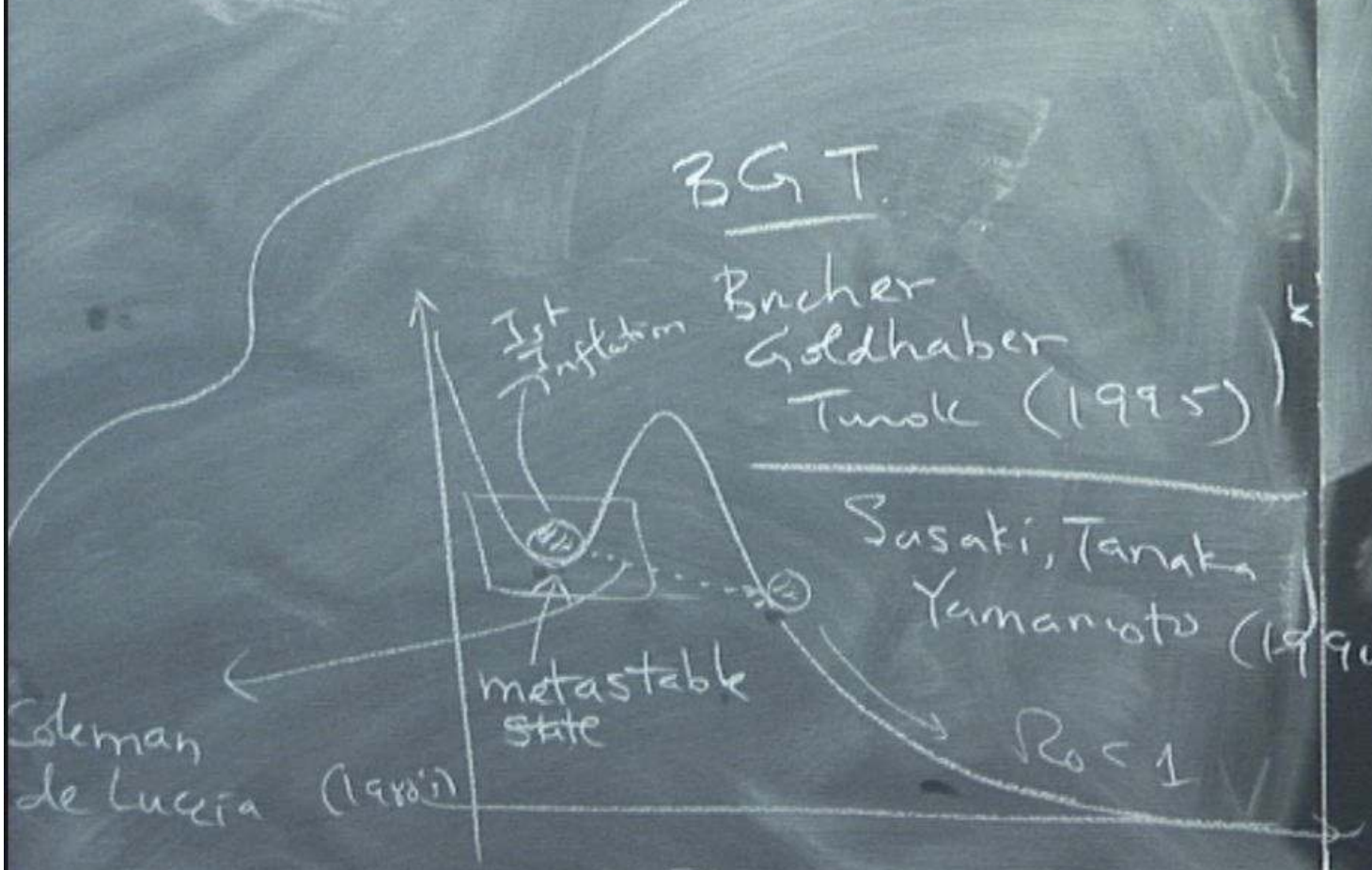
$\dot{a} = 1$, $a = 0$, $\varphi = 0$

(94-96)

$$\Omega - 1 = \frac{k}{a^2 H^2} = \frac{kc}{\dot{q}^2} \Rightarrow \Omega - 1 = k = -1$$

$$\Omega = 0$$

BGT



* $\Omega_0 < 1$

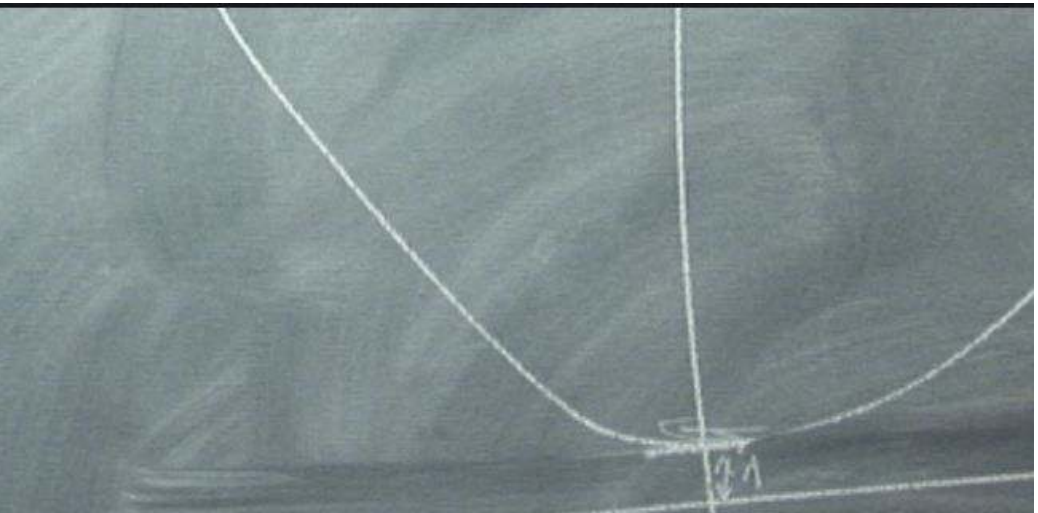
*. No physical singularity.

$V(\varphi) = \frac{V_0}{\varphi}$

* In

à

$$V(\varphi) = \frac{V_0}{\varphi^\alpha}$$



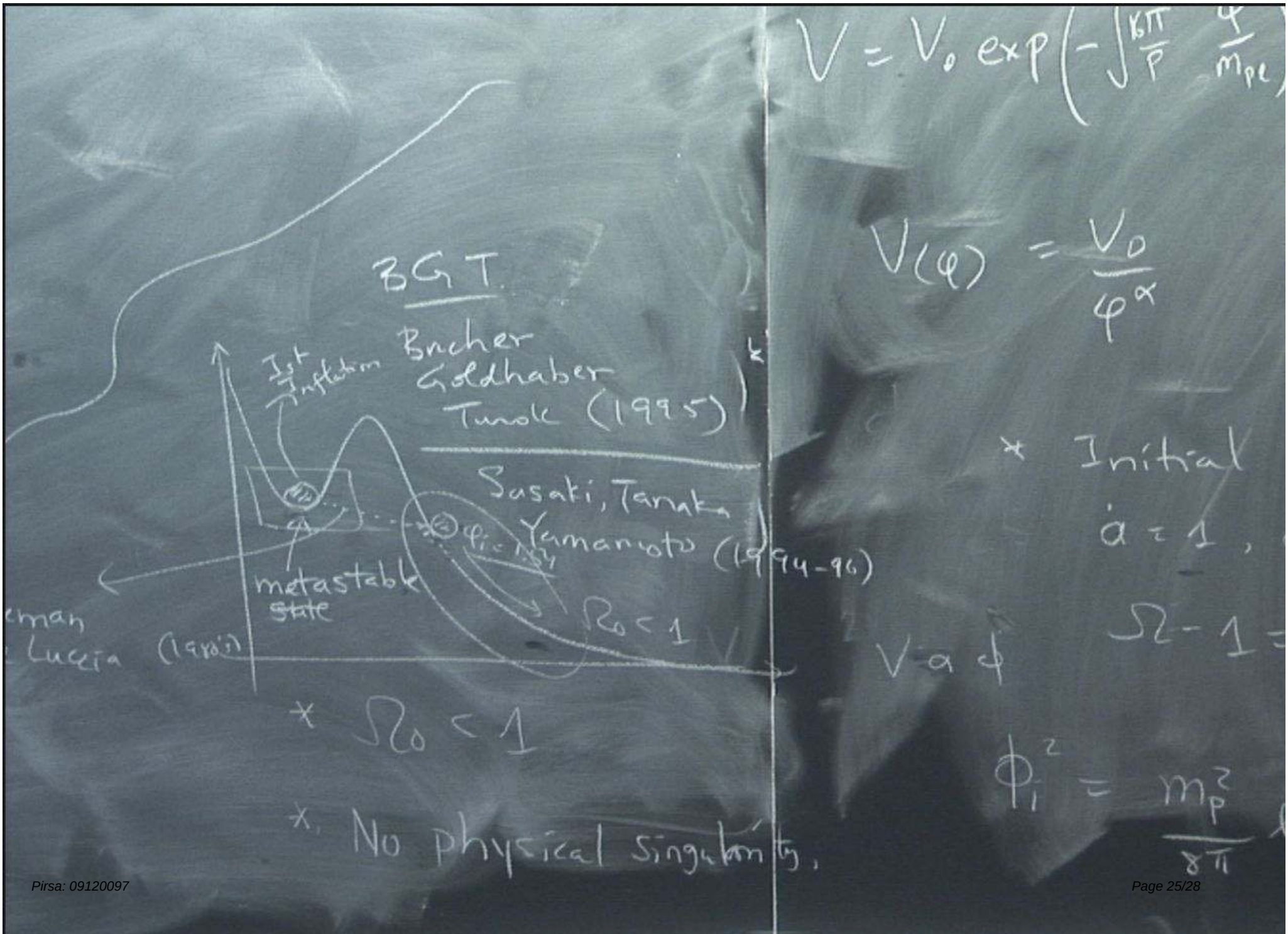
* Initial conditions of bubble.

$$\dot{a} = 1 \,, \quad a = 0 \,, \quad \dot{\varphi} = 0$$

$$\Omega - 1 = \frac{k}{a^2 H^2} = \frac{k}{\dot{\varphi}^2} \Rightarrow \Omega - 1 = K = -1$$

$$\Omega = 0$$

(1994-96)


BGT
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Goldhaber
Turok (1995)
Sasaki, Tanaka
Yamamoto (1994-96)
1st Inflation
metastable state
$\Omega_0 < 1$
* $\Omega_0 < 1$
* No physical singularity.
$V = V_0 \exp\left(-\sqrt{\frac{16\pi}{p}}\ \frac{\varphi}{m_{pl}}\right)$
$V(\varphi) = \frac{V_0}{\varphi^\alpha}$
* Initial
$\dot{a} = 1$,
$\Omega - 1 =$
$V \propto \phi$
$\phi_i^2 = \frac{m_p^2}{8\pi}$

$$V = V_0 \exp\left(-\sqrt{\frac{k\pi}{p}}\,\frac{\varphi}{m_{pl}}\right)$$

$$V(\varphi) = \frac{V_0}{\varphi^\alpha}$$

BGT

1st Inflation

Bucher Goldhaber Turok (1995)

Susaki, Tanaka, Yamamoto (1994-96)

metastable state

$\Omega_0 = 1$

$V \sim \phi$

* $\Omega_0 < 1$

* No physical singularity.

* Initial condition of bubble

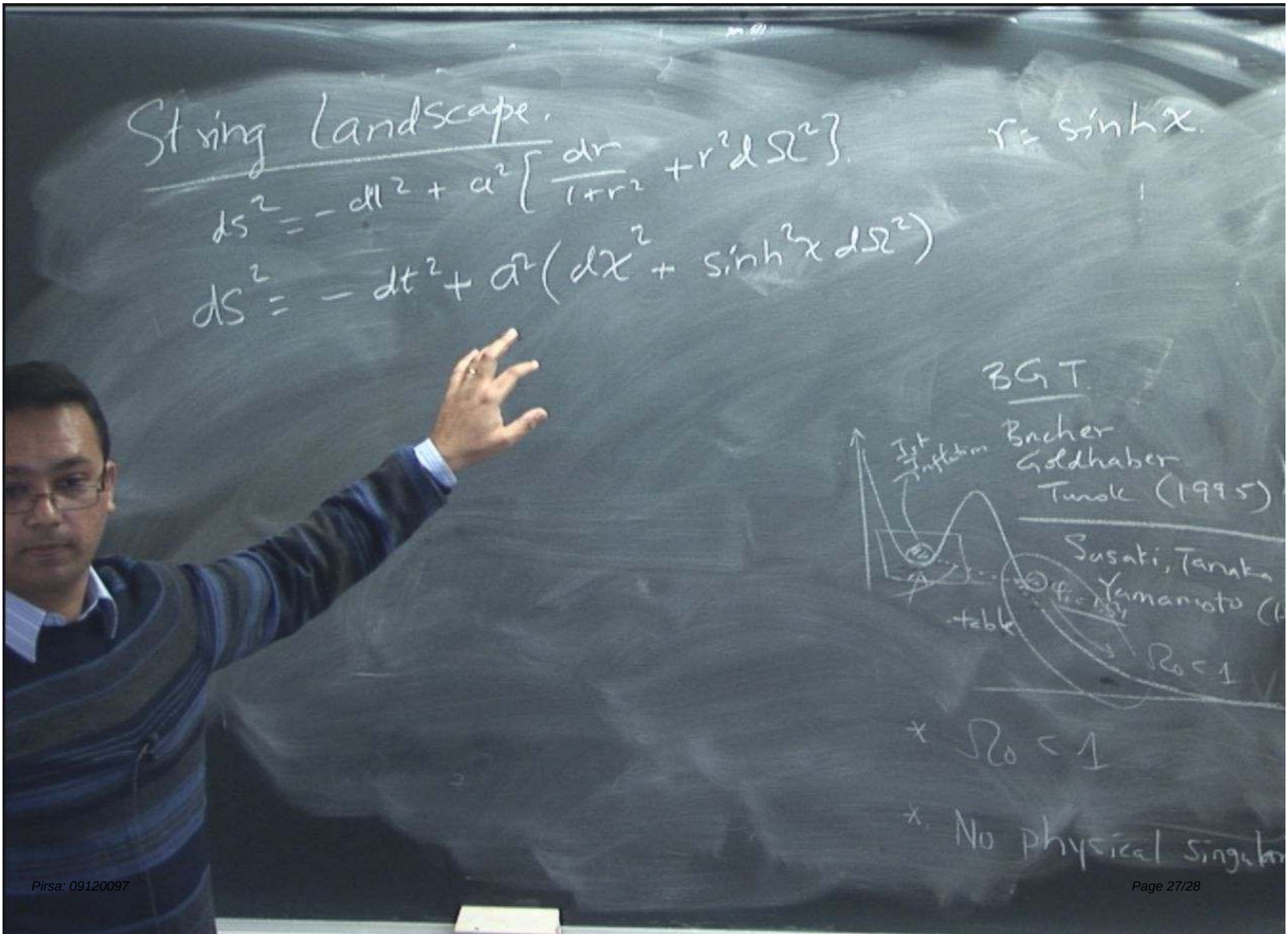
$\dot{a} = 1$, $a = 0$, $\varphi = 0$

$$\Omega - 1 = \frac{k}{a^2 H^2} = \frac{k}{\dot{a}^2} \Rightarrow \Omega - 1 = k = -1$$

$\Omega = 0$

$$\phi_i^2 = \frac{m_p^2}{8\pi} \ln\left[\frac{A}{\Omega_0^{-1} - 1}\right]$$

$A \sim 10^{15}$


String landscape.
$ds^2 = -dt^2 + a^2\left[\frac{dr}{1+r^2} + r^2 d\Omega^2\right]$.
$r = \sinh x$.
$ds^2 = -dt^2 + a^2(dx^2 + \sinh^2 x\, d\Omega^2)$
BGT
Bucher
Goldhaber
Turok (1995)
Susaki, Tanaka
Yamamoto
$\Omega_0 < 1$
* $\Omega_0 < 1$
* No physical

String landscape.

$$ds^2 = -dt^2 + a^2\left[\frac{dr}{1+r^2} + r^2 d\Omega^2\right] \qquad r = \sinh\chi.$$

$$ds^2 = -dt^2 + t^2\left(d\chi^2 + \sinh^2\chi\, d\Omega^2\right)$$

Near the singularity.

Milne metric

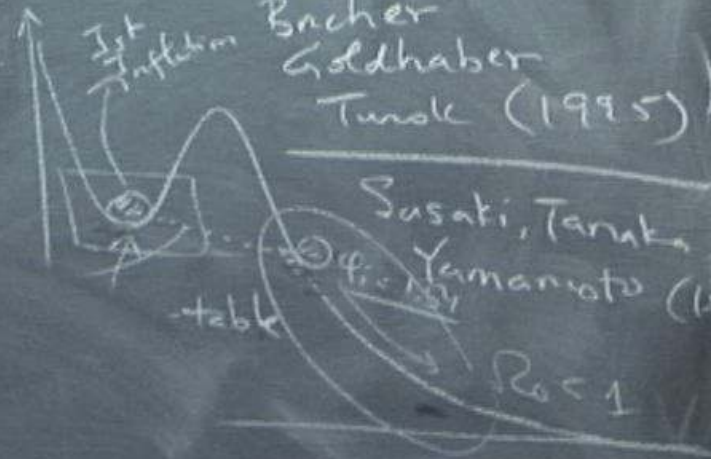
$$T = t\cosh\chi$$

$$R = t\sinh\chi$$

$$ds^2 = -dT^2 + (dR^2 + R^2 d\Omega^2)$$

BGT

Bucher Goldhaber Turok (1995)



Susaki, Tanaka, Yamamoto (

* $\Omega_0 < 1$

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