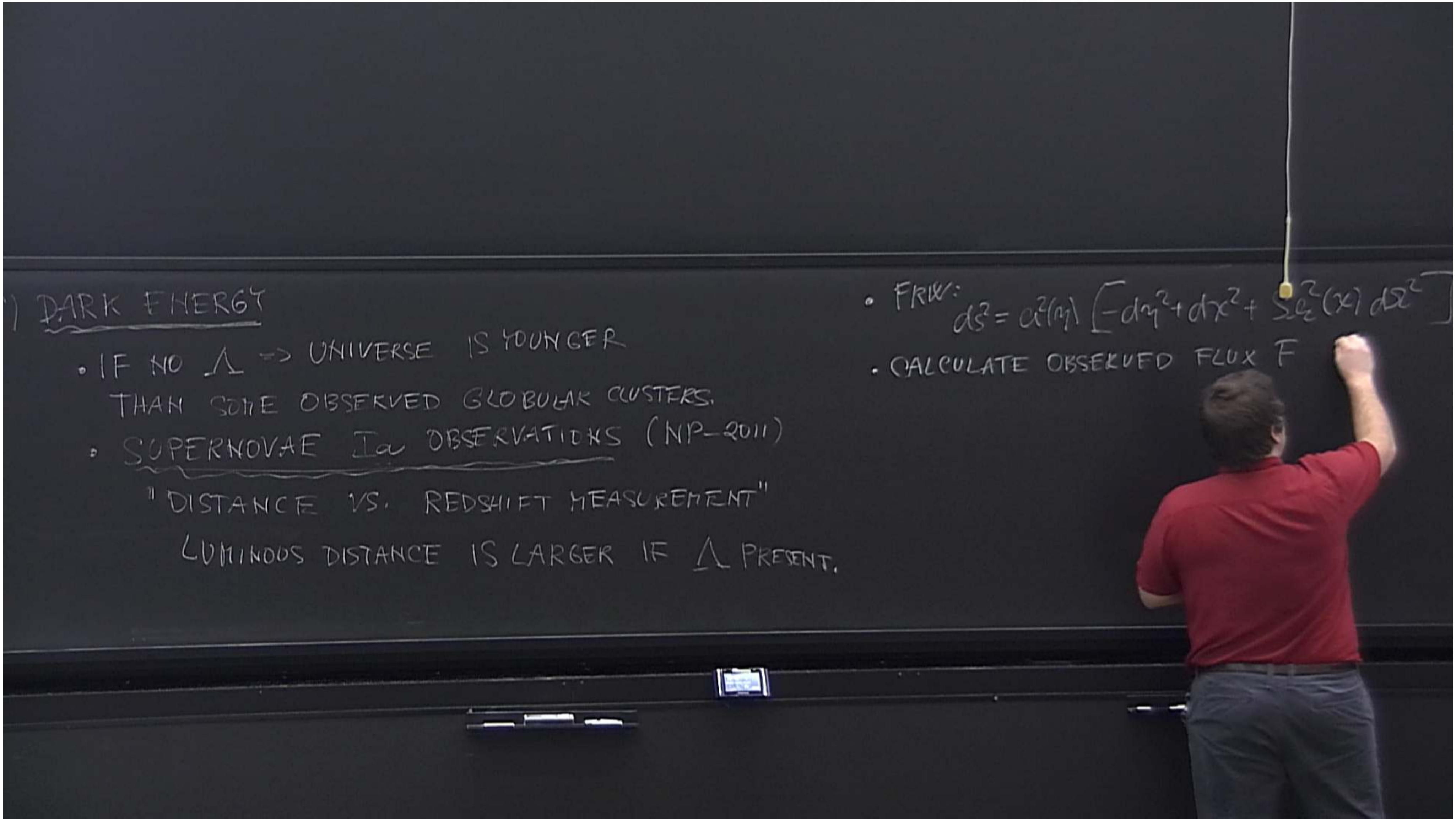
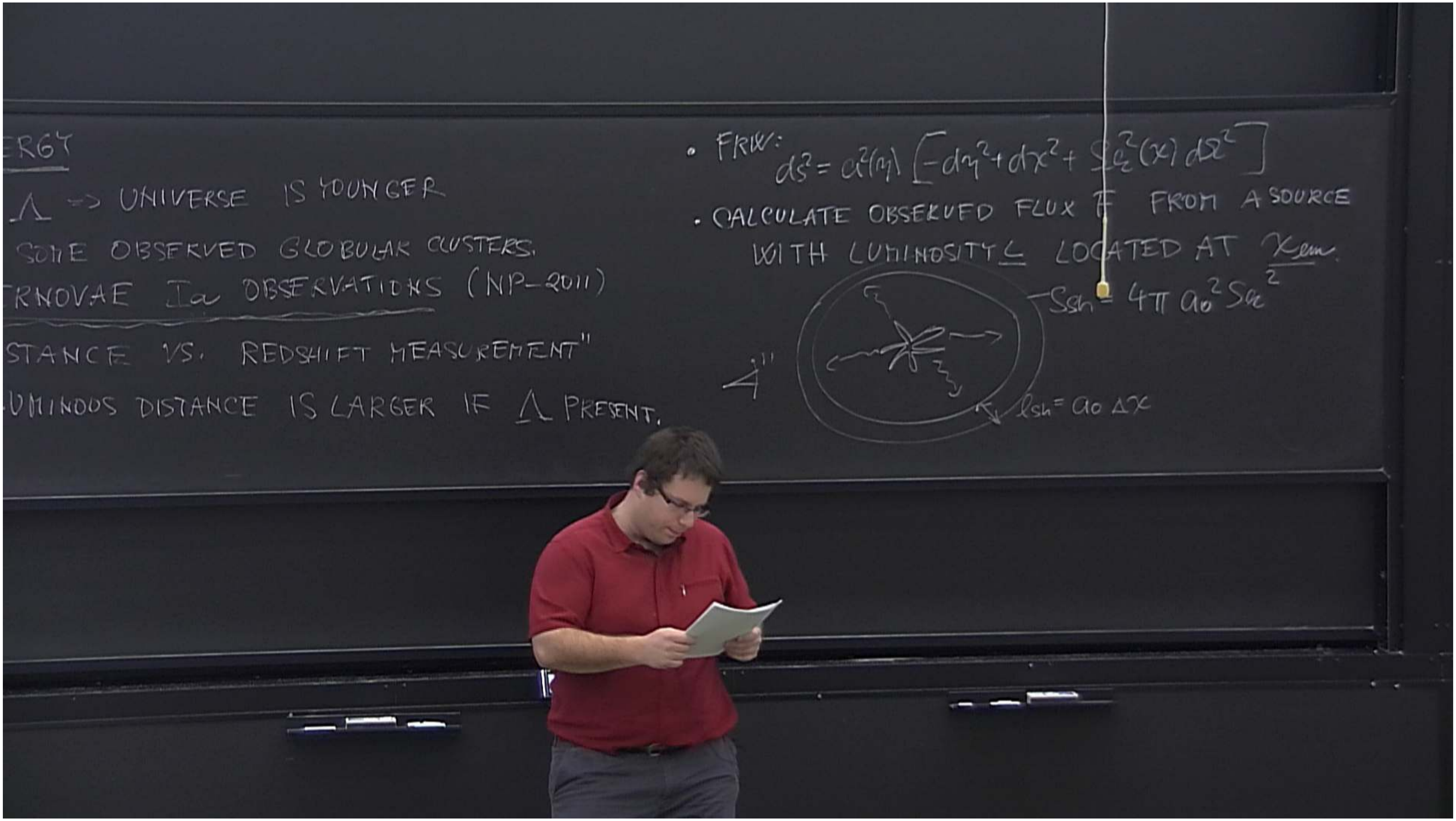
Title: PSI 2015/2016 Cosmology - Lecture 8

Date: Feb 10, 2016 11:30 AM

URL: http://pirsa.org/16020058

Abstract:


DARK ENERGY
• IF NO Λ => UNIVERSE IS YOUNGER
THAN SOME OBSERVED GLOBULAR CLUSTERS.
• SUPERNOVAE Ia OBSERVATIONS (NP-2011)
"DISTANCE VS. REDSHIFT MEASUREMENT"
LUMINOUS DISTANCE IS LARGER IF Λ PRESENT.
• FRW: $ds^2 = a^2(\eta)\left[-d\eta^2 + d\chi^2 + S_k^2(\chi)\, d\Omega^2\right]$
• CALCULATE OBSERVED FLUX F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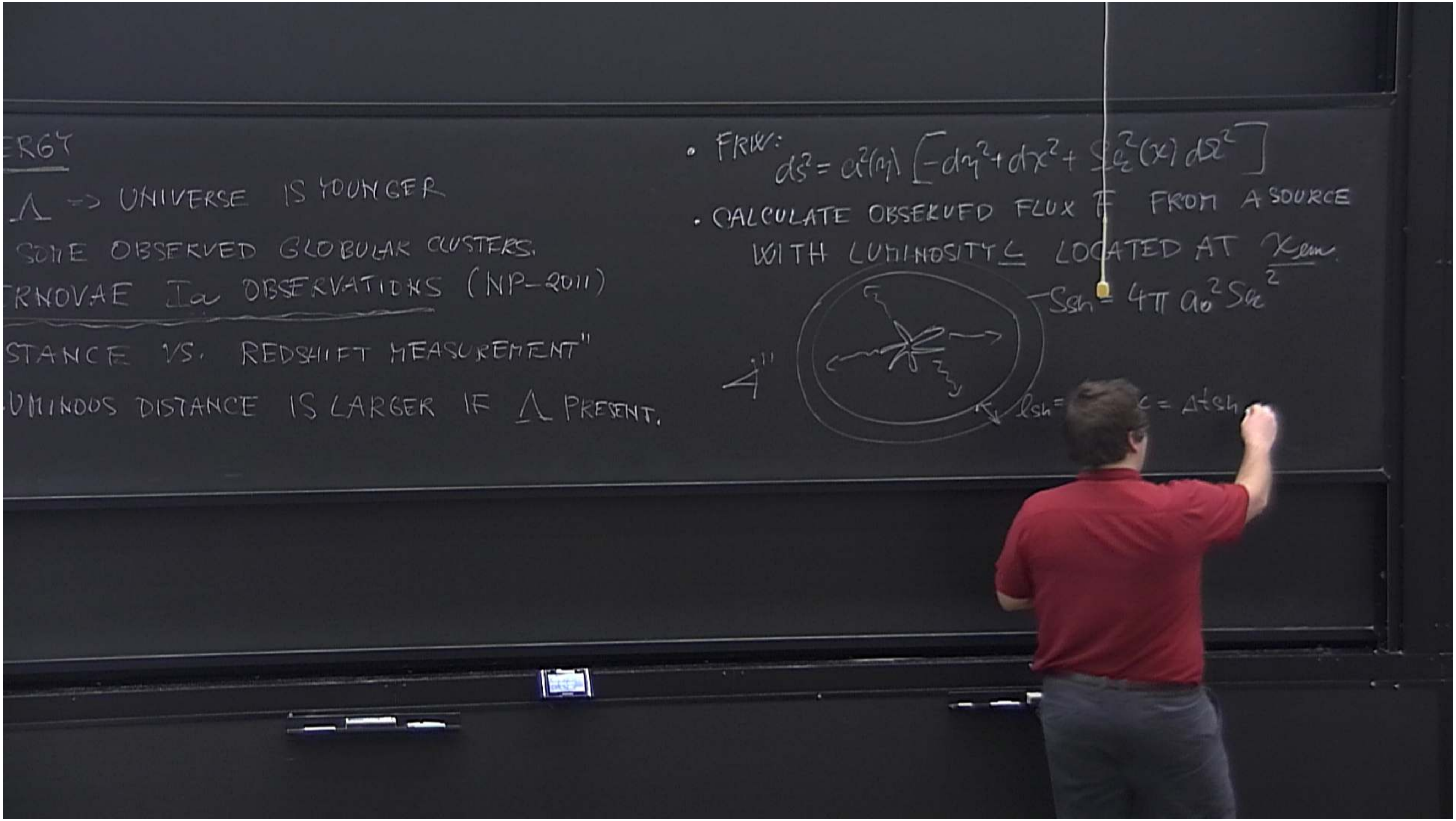
• FRW: $ds^2 = a^2(\eta)\left[-d\eta^2 + d\chi^2 + S_k^2(\chi)\, d\Omega^2\right]$
• CALCULATE OBSERVED FLUX F FROM A SOURCE
WITH LUMINOSITY L LOCATED AT χ_{em}.
$S_{sh} = 4\pi a_0^2 S_k^2$
$l_{sh} = a_0 \Delta\chi$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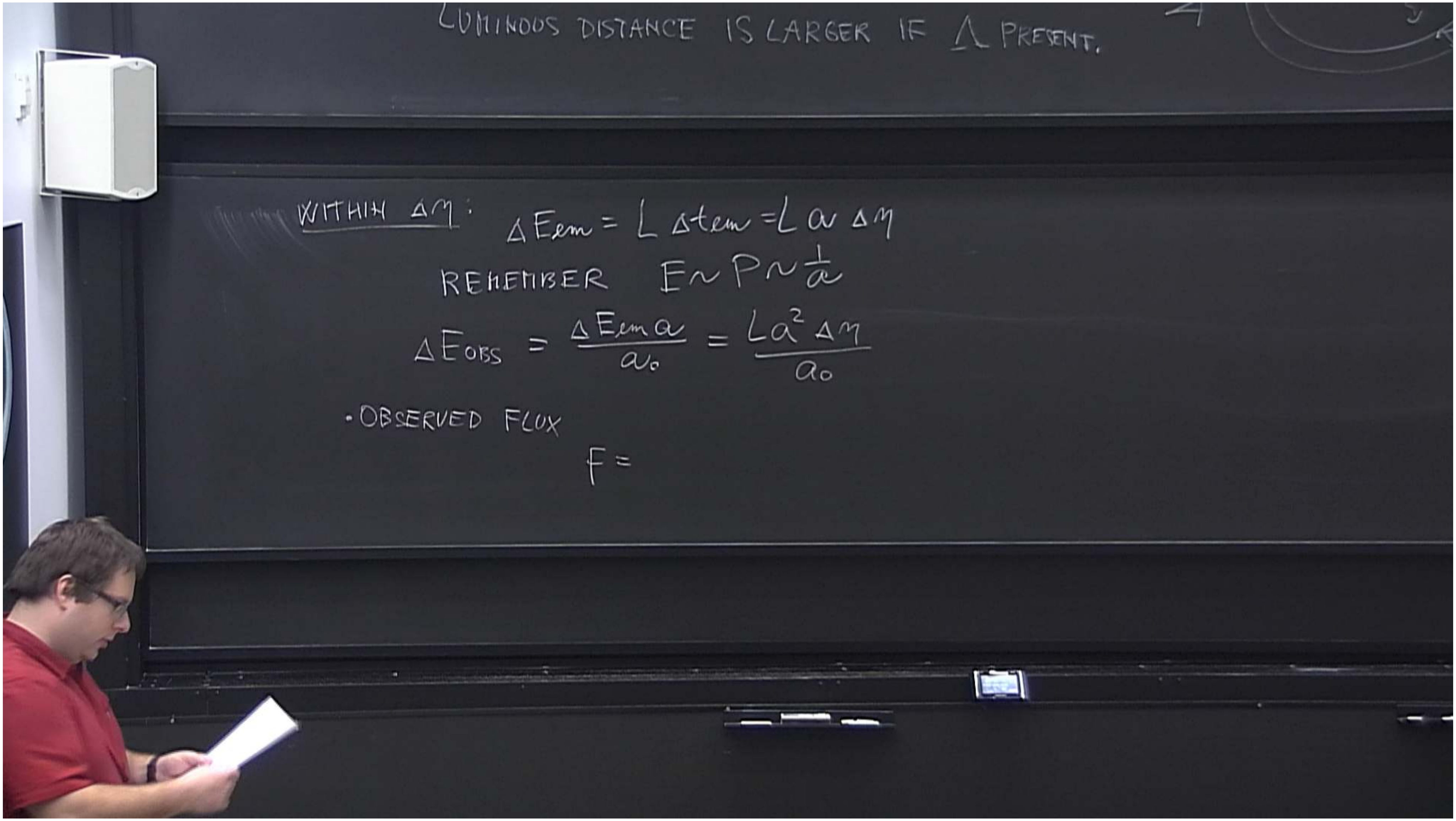
RNOVAE Ia OBSERVATIONS (NP-2011)
STANCE VS. REDSHIFT MEASUREMENT"
UMINOUS DISTANCE IS LARGER IF Λ PRESENT.
• FRW: ds² = a²(η) [-dη² + dχ² + S_k²(χ) dΩ²]
• CALCULATE OBSERVED FLUX F FROM A SOURCE
WITH LUMINOSITY L LOCATED AT χ_em.
S_sh = 4π a₀² S_k²
l_sh = Δt_sh


LUMINOUS DISTANCE IS LARGER IF Λ PRESENT.
WITHIN $\Delta\eta$: $\Delta E_{em} = L \Delta t_{em} = L a \Delta\eta$
REMEMBER $E \sim P \sim \frac{1}{a}$
$\Delta E_{OBS} = \frac{\Delta E_{em} a}{a_0} = \frac{L a^2 \Delta\eta}{a_0}$
• OBSERVED FLUX
$F =$

LUMINOUS DISTANCE IS LARGER IF Λ PRESENT.

$l_{sh} = a_0 \Delta x = \Delta t$

WITHIN $\Delta\eta$: $\Delta E_{em} = L\,\Delta t_{em} = L\,a\,\Delta\eta$

REMEMBER $E \sim P \sim \frac{1}{a}$

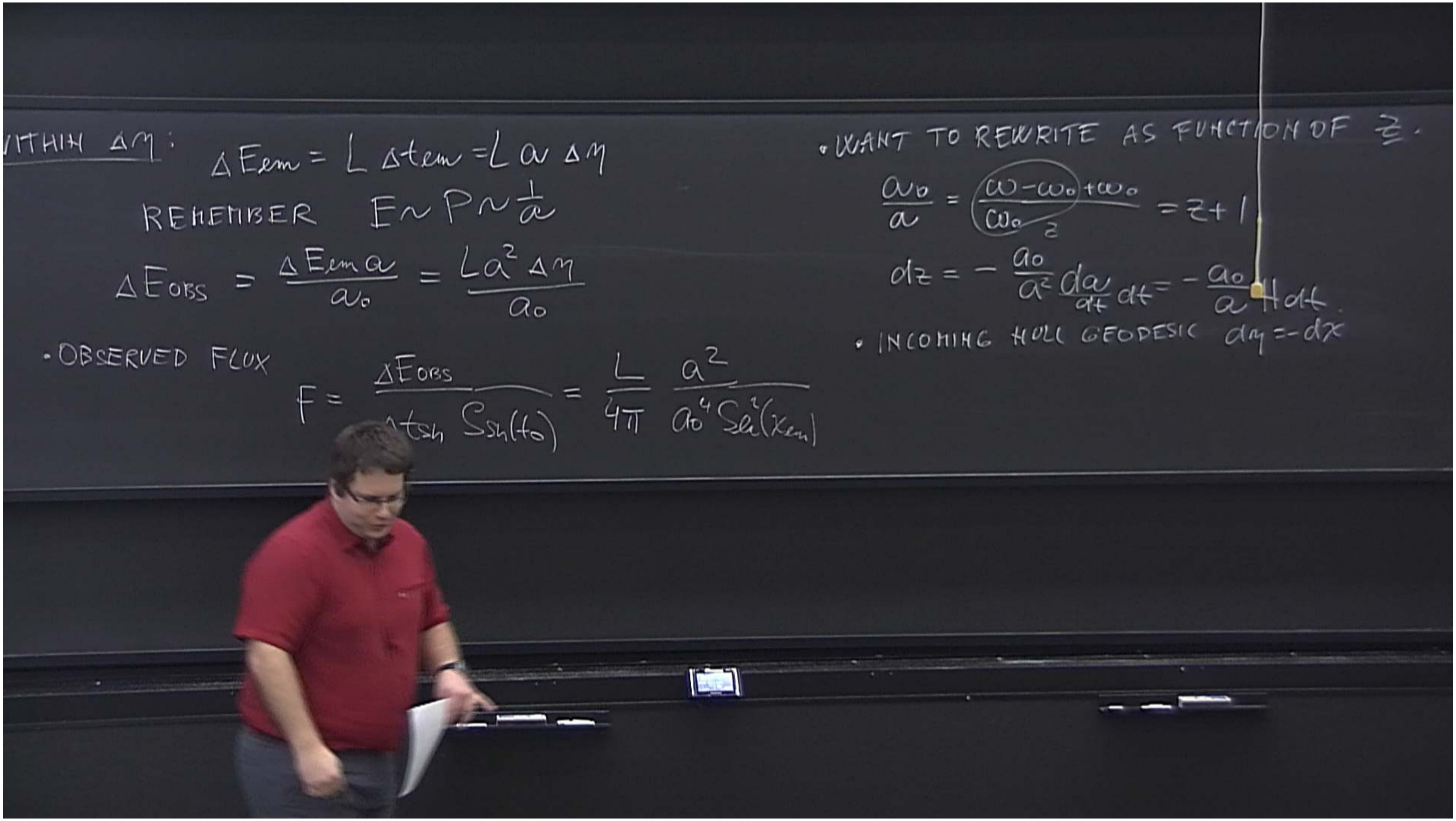
$$\Delta E_{OBS} = \frac{\Delta E_{em}\,a}{a_0} = \frac{L a^2 \Delta\eta}{a_0}$$

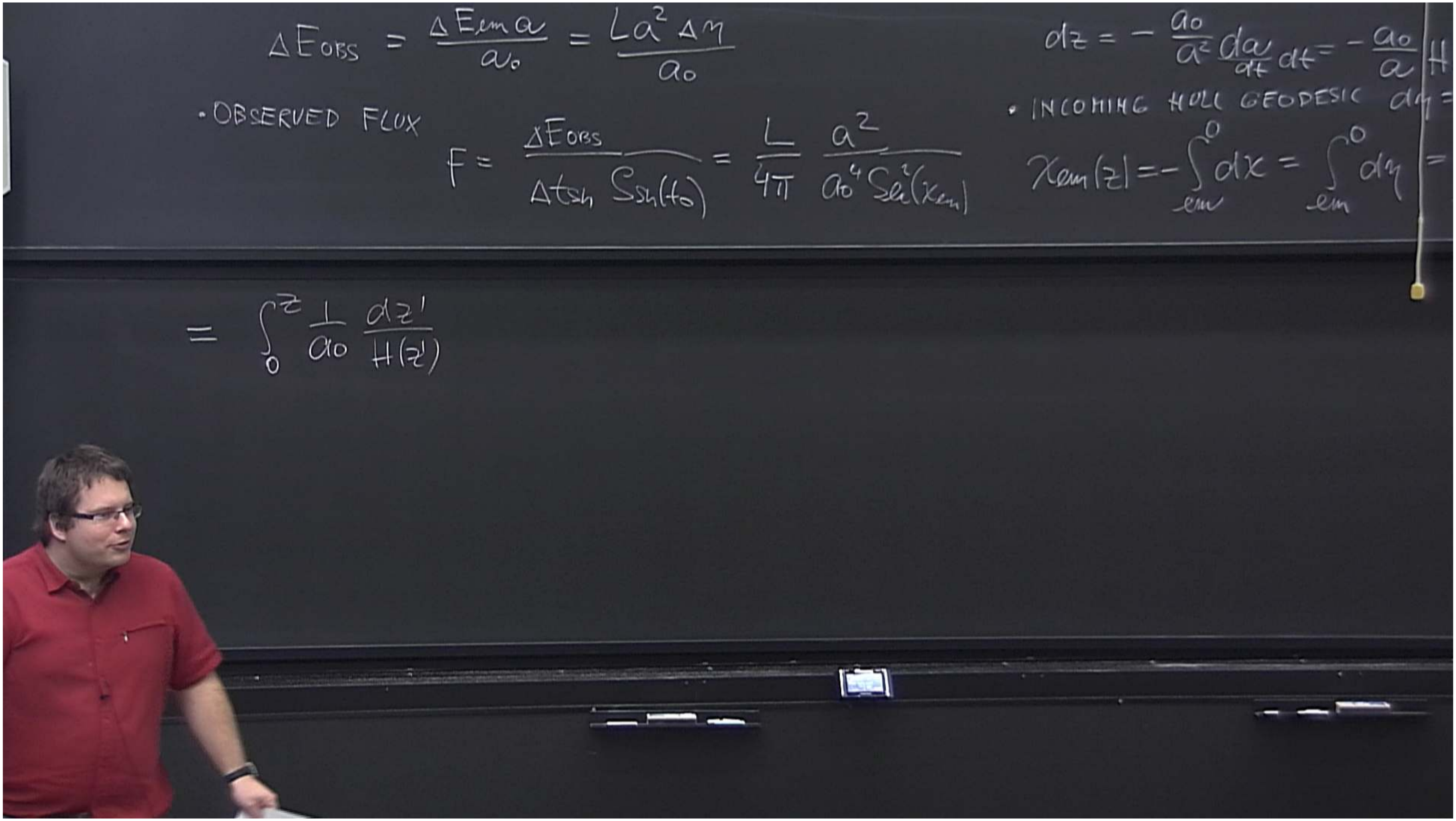
• OBSERVED FLUX

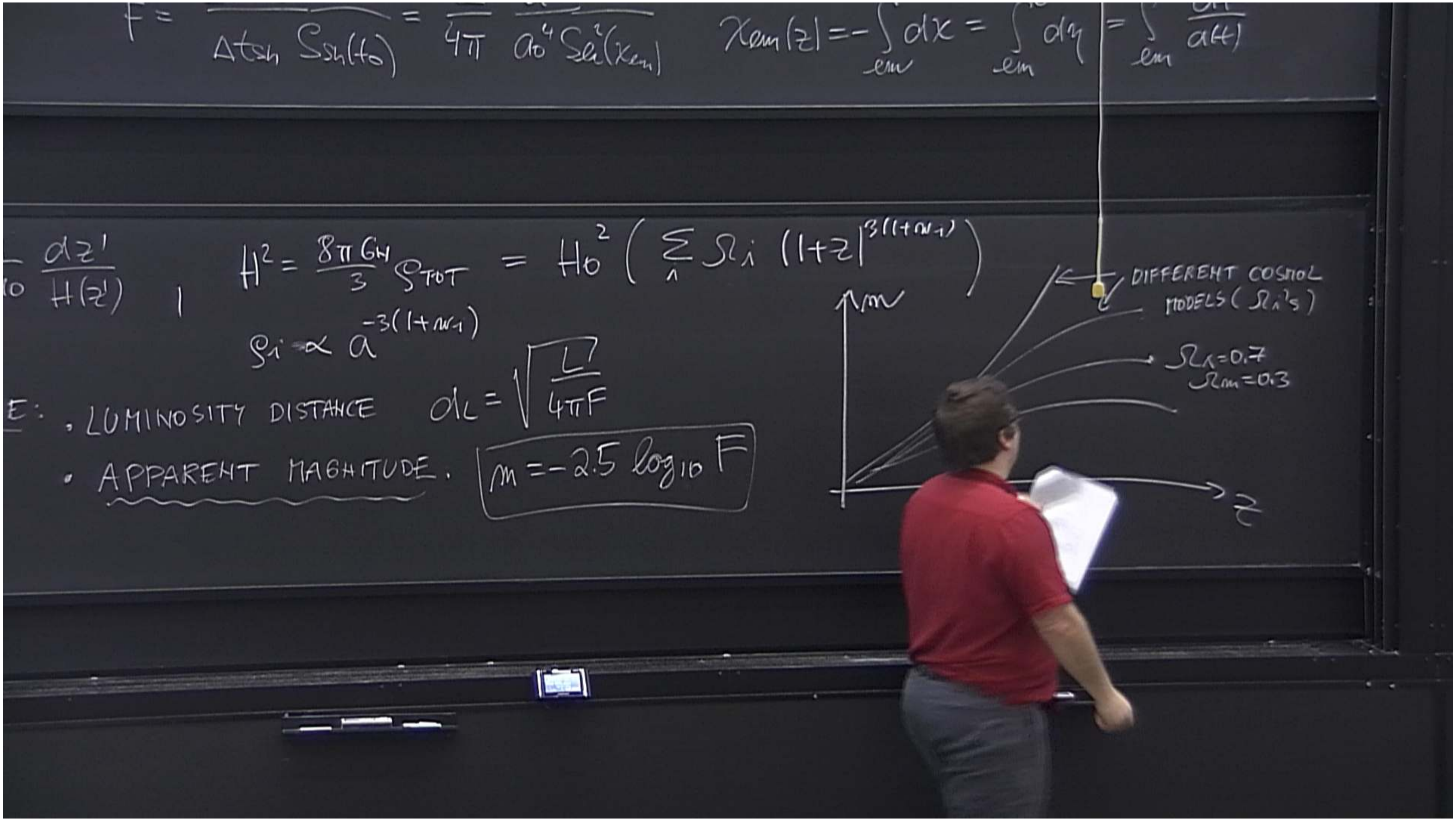
$$F = \frac{\Delta E_{OBS}}{\Delta t_{sh}\; S_{sh}(t_0)} = \frac{L}{4\pi}\,\frac{a^2}{a_0^4 S}$$

• WANT TO REWRITE AS FUNCTION OF

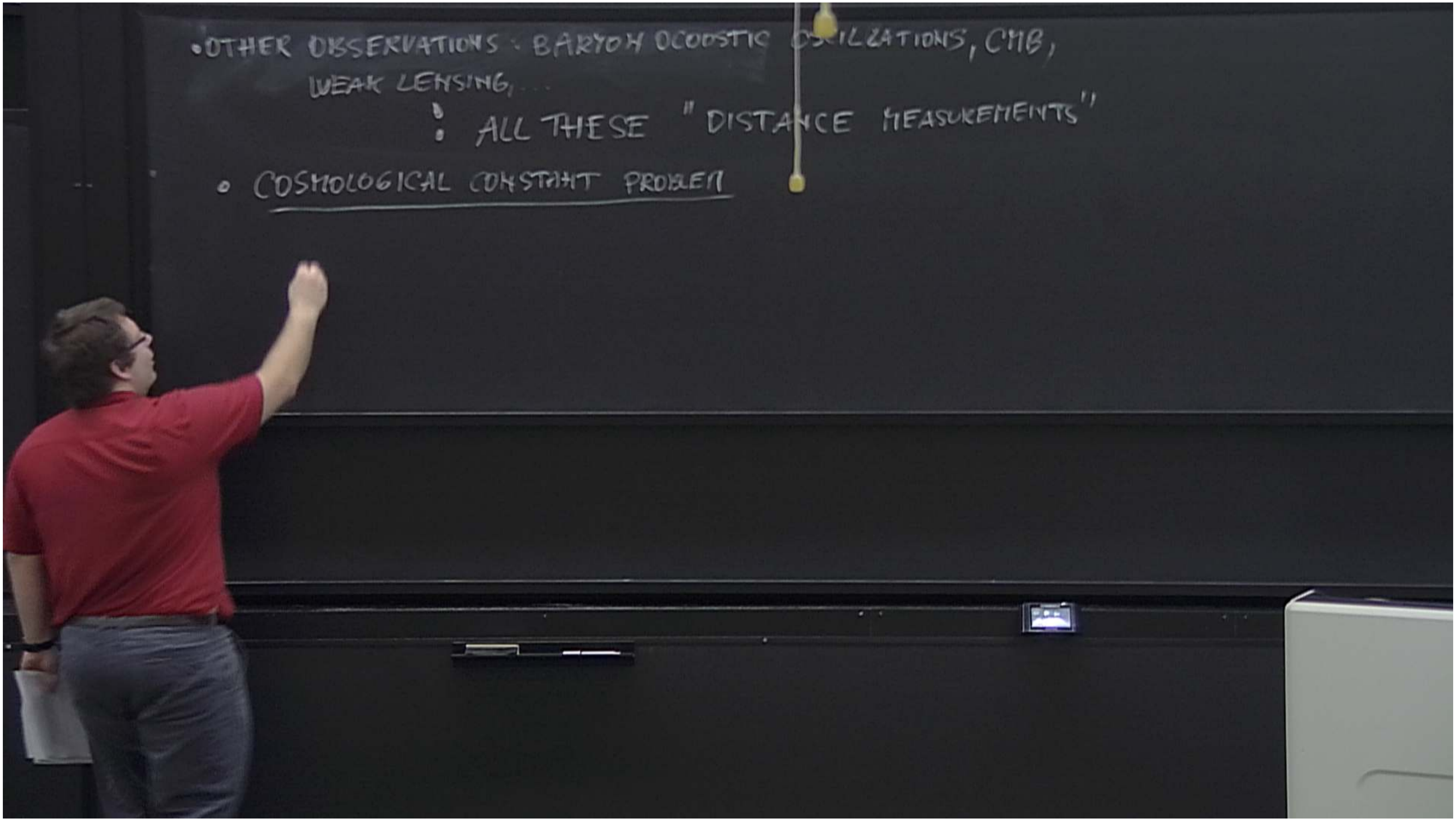
$$\frac{a_0}{a} =$$


WITHIN $\Delta\eta$:
$\Delta E_{em} = L \, \Delta t_{em} = L \, a \, \Delta\eta$
REMEMBER $E \sim P \sim \frac{1}{a}$
$\Delta E_{OBS} = \frac{\Delta E_{em} \, a}{a_0} = \frac{L a^2 \Delta\eta}{a_0}$
• OBSERVED FLUX
$F = \frac{\Delta E_{OBS}}{\Delta t_{sh} \, S_{sh}(t_0)} = \frac{L}{4\pi} \frac{a^2}{a_0^4 \, S_k^2(\chi_{em})}$
• WANT TO REWRITE AS FUNCTION OF z.
$\frac{a_0}{a} = \frac{\omega - \omega_0 + \omega_0}{\omega_0} = z + 1$
$dz = -\frac{a_0}{a^2} \frac{da}{dt} dt = -\frac{a_0}{a} H dt$.
• INCOMING NULL GEODESIC $d\eta = -d\chi$

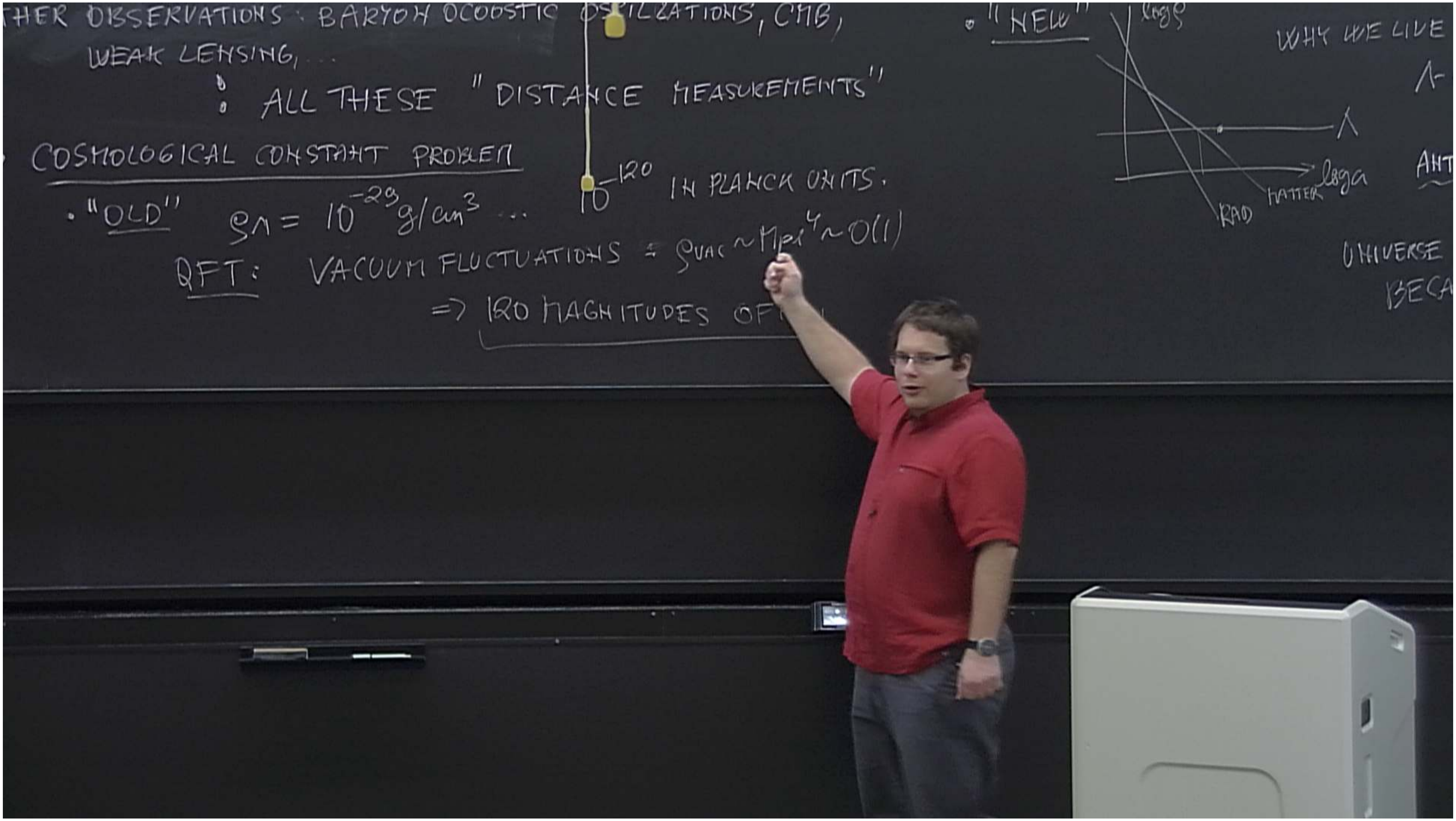

$\Delta E_{OBS} = \frac{\Delta E_{em} a}{a_0} = \frac{L a^2 \Delta \eta}{a_0}$
• OBSERVED FLUX
$F = \frac{\Delta E_{OBS}}{\Delta t_{sh} S_{sh}(t_0)} = \frac{L}{4\pi} \frac{a^2}{a_0^4 S_k^2(\chi_{em})}$
$dz = -\frac{a_0}{a^2}\frac{da}{dt} dt = -\frac{a_0}{a} H$
• INCOMING NULL GEODESIC $d\eta =$
$\chi_{em}(z) = -\int_{em}^{0} d\chi = \int_{em}^{0} d\eta =$
$= \int_0^z \frac{1}{a_0} \frac{dz'}{H(z')}$



Atsh Ssh(to)
4π ao⁴ Ssh²(χem)
χem(z) = -∫ dx = ∫ dη = ∫ dt/a(t)
dz'/H(z')
H² = 8πGN/3 ρTOT = Ho² (Σi Ωi (1+z)^3(1+wi))
ρi ∝ a^-3(1+wi)
LUMINOSITY DISTANCE dL = √(L/4πF)
APPARENT MAGNITUDE. m = -2.5 log10 F
DIFFERENT COSMOL MODELS (Ωi's)
ΩΛ=0.7
Ωm=0.3
m
z



• OTHER OBSERVATIONS: BARYON ACOUSTIC OSCILLATIONS, CMB,
WEAK LENSING, ...
: ALL THESE "DISTANCE MEASUREMENTS"
• COSMOLOGICAL CONSTANT PROBLEM

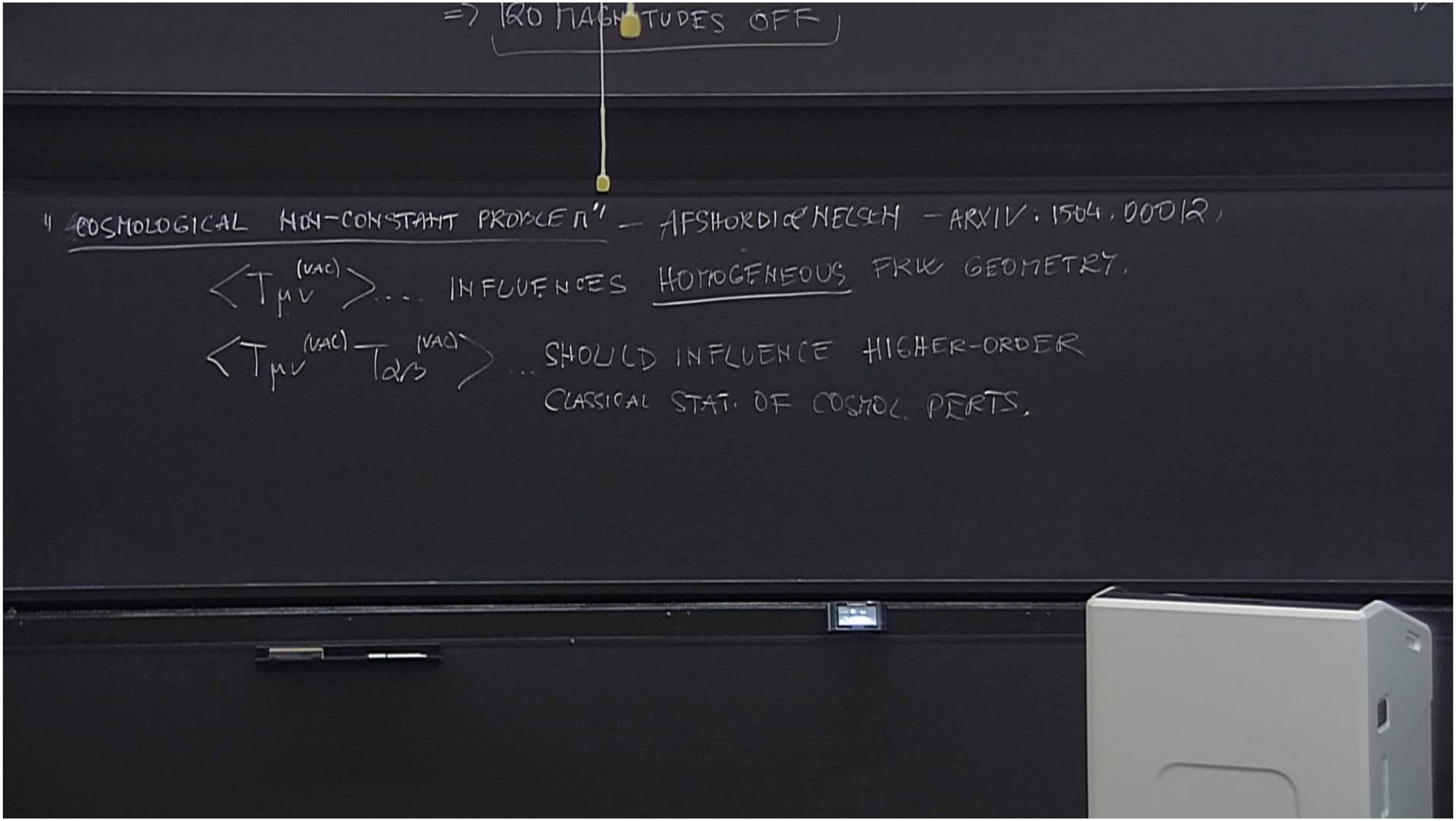

THER OBSERVATIONS : BARYON OCOUSTIC OSCILLATIONS, CMB,
WEAK LENSING, ...
ALL THESE "DISTANCE MEASUREMENTS"
COSMOLOGICAL CONSTANT PROBLEM
"OLD" ρΛ = 10^-29 g/cm^3 ... 10^-120 IN PLANCK UNITS.
QFT: VACUUM FLUCTUATIONS ⇒ ρvac ~ Mpl^4 ~ O(1)
⇒ 120 MAGNITUDES OF
"NEW"
log ρ
Λ
log a
RAD
MATTER
WHY WE LIVE
UNIVERSE
BECA

$\Rightarrow$ 120 MAGNITUDES OFF

"COSMOLOGICAL NON-CONSTANT PROBLEM" – AFSHORDI & NELSON – ARXIV: 1504.00012.

$\langle T_{\mu\nu}^{(VAC)} \rangle$ ... INFLUENCES HOMOGENEOUS FRW GEOMETRY.

$\langle T_{\mu\nu}^{(VAC)} T_{\alpha\beta}^{(VAC)} \rangle$ ... SHOULD INFLUENCE HIGHER-ORDER CLASSICAL STAT. OF COSMOL. PERTS.


⇒ 120 MAGNITUDES OFF
4 "COSMOLOGICAL NON-CONSTANT PROBLEM" – AFSHORDI & NELSON – ARXIV: 1504.00012,
$\langle T_{\mu\nu}^{(VAC)} \rangle$ ... INFLUENCES HOMOGENEOUS FRW GEOMETRY.
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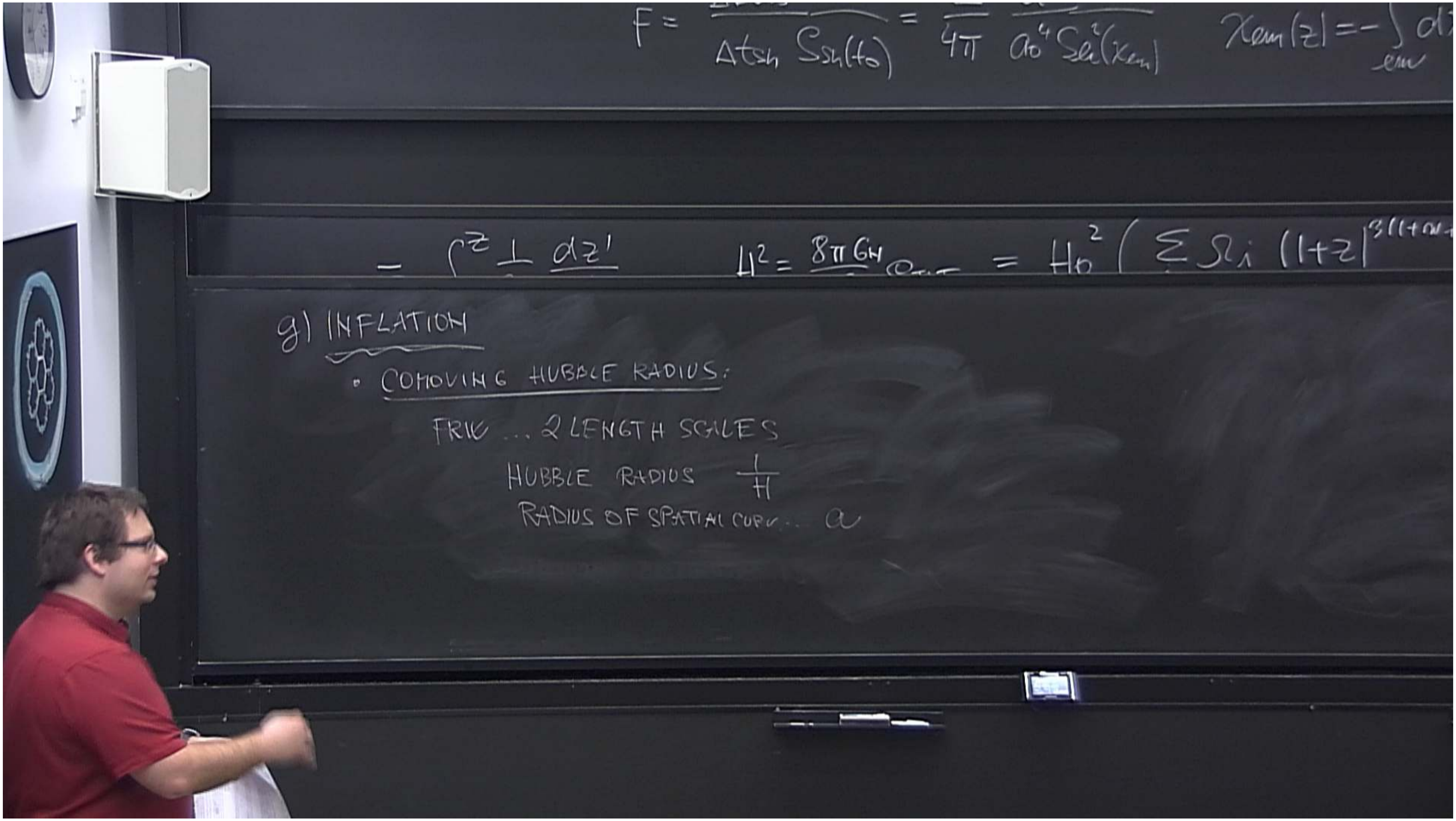
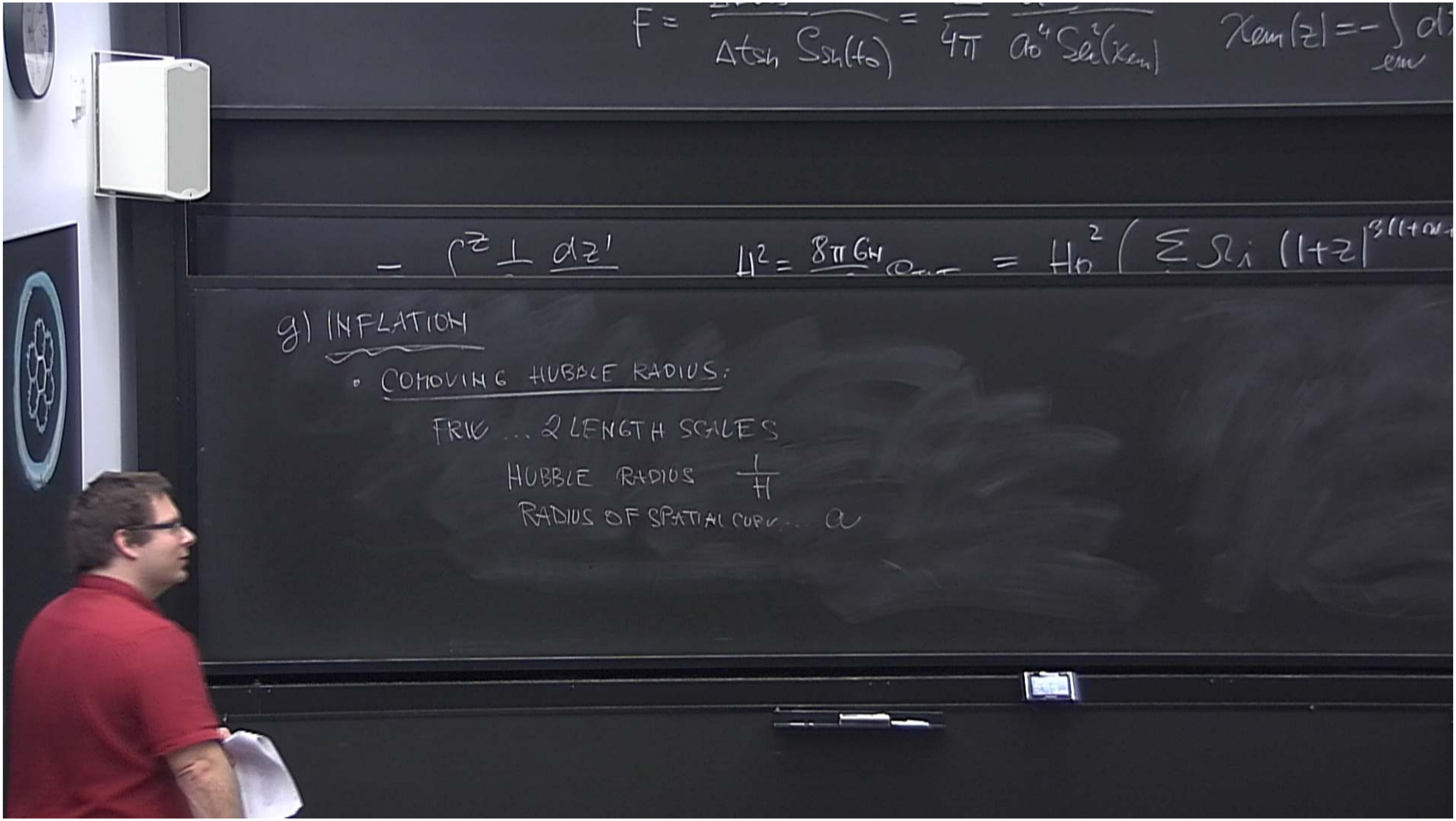

g) INFLATION
COMOVING HUBBLE RADIUS:
FRW ... 2 LENGTH SCALES
HUBBLE RADIUS 1/H
RADIUS OF SPATIAL CURV... a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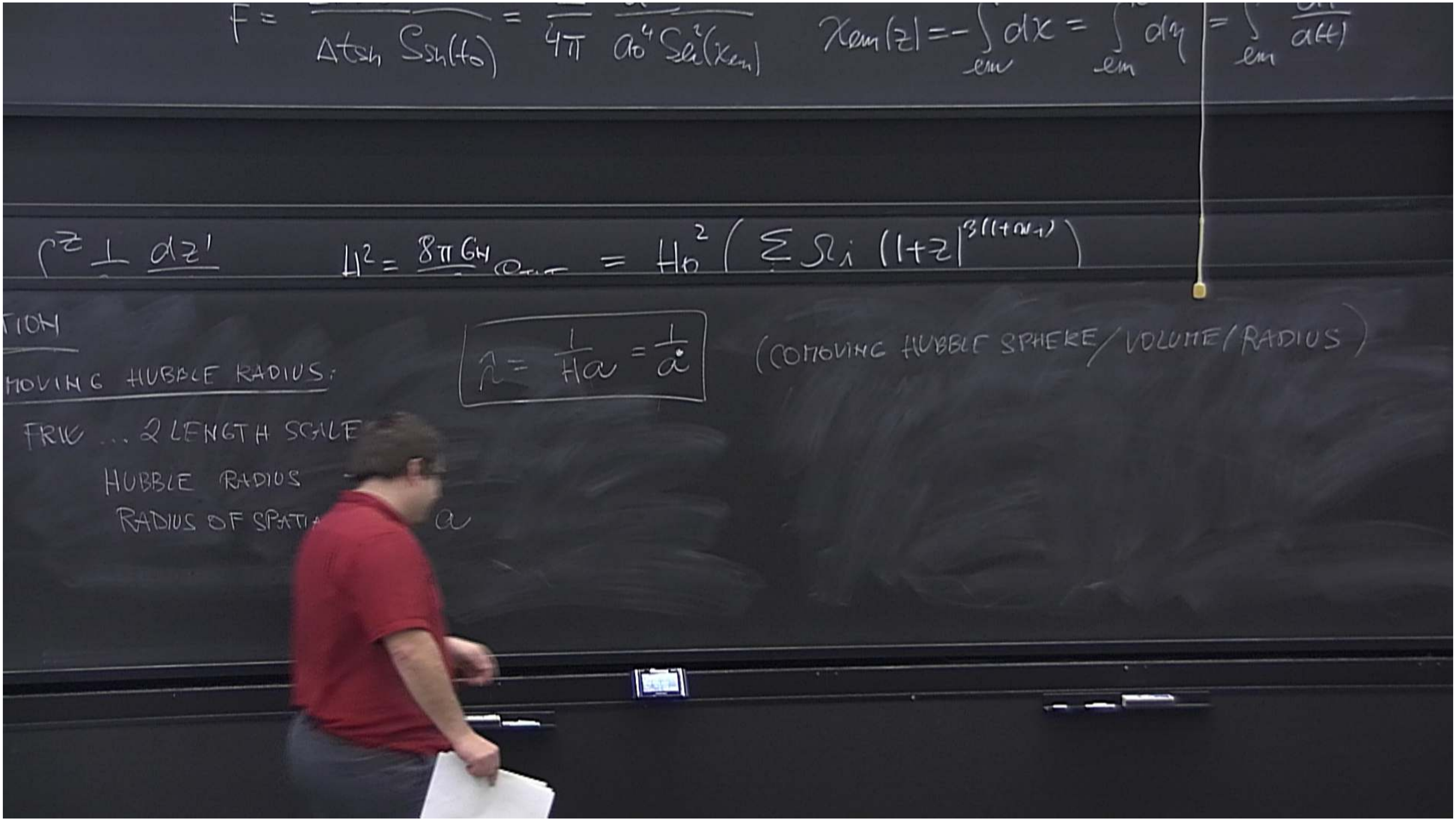
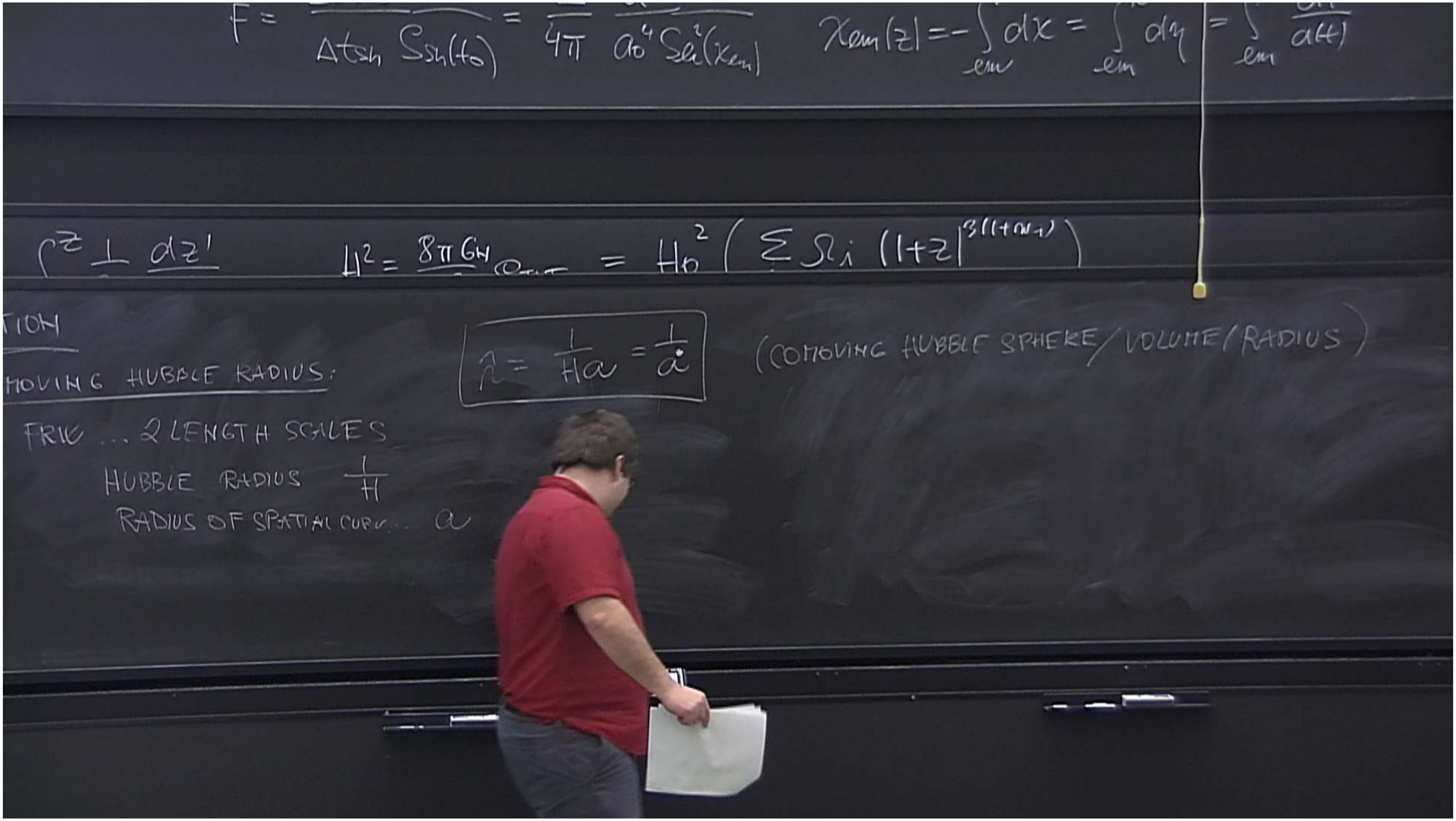
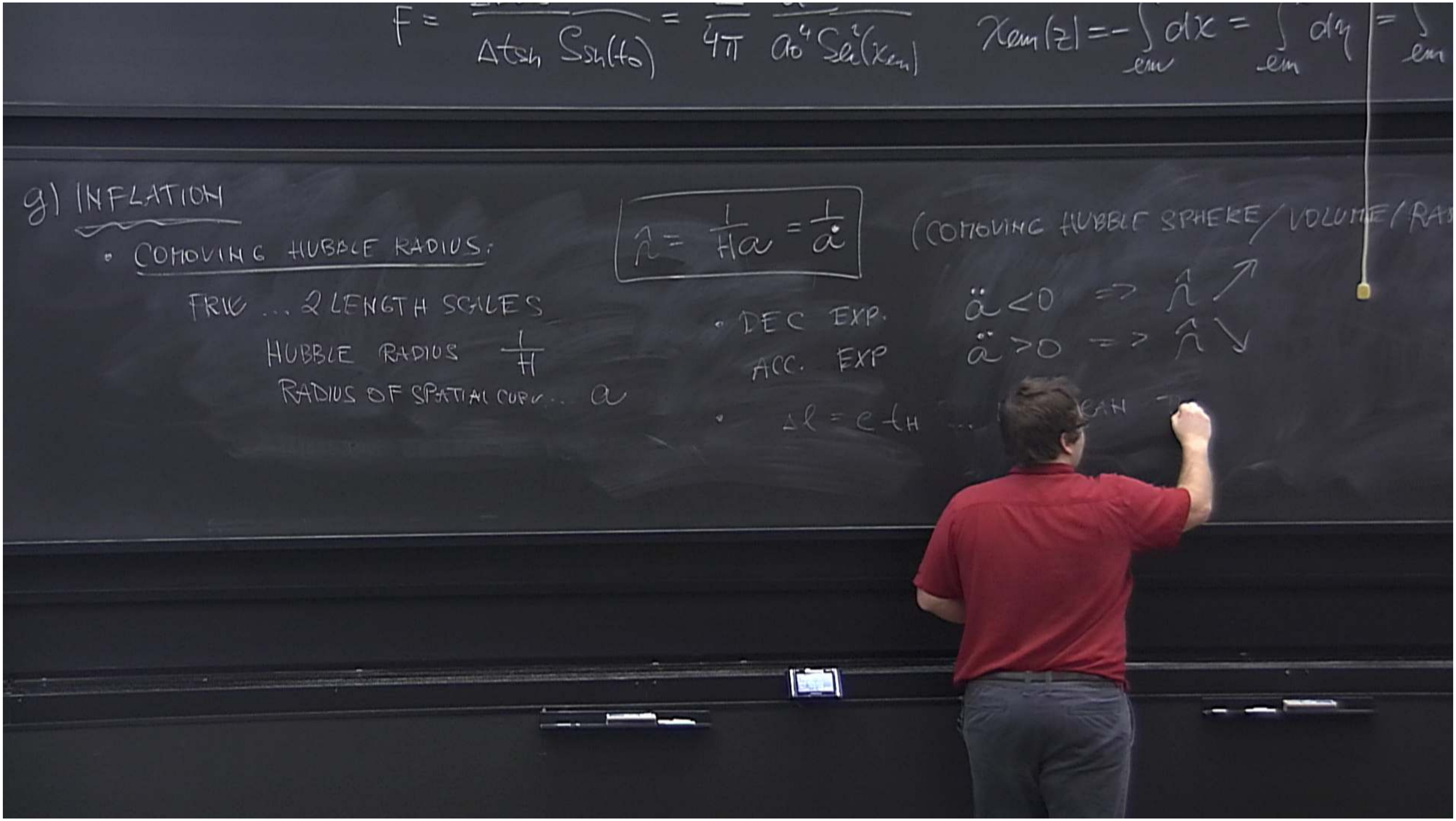
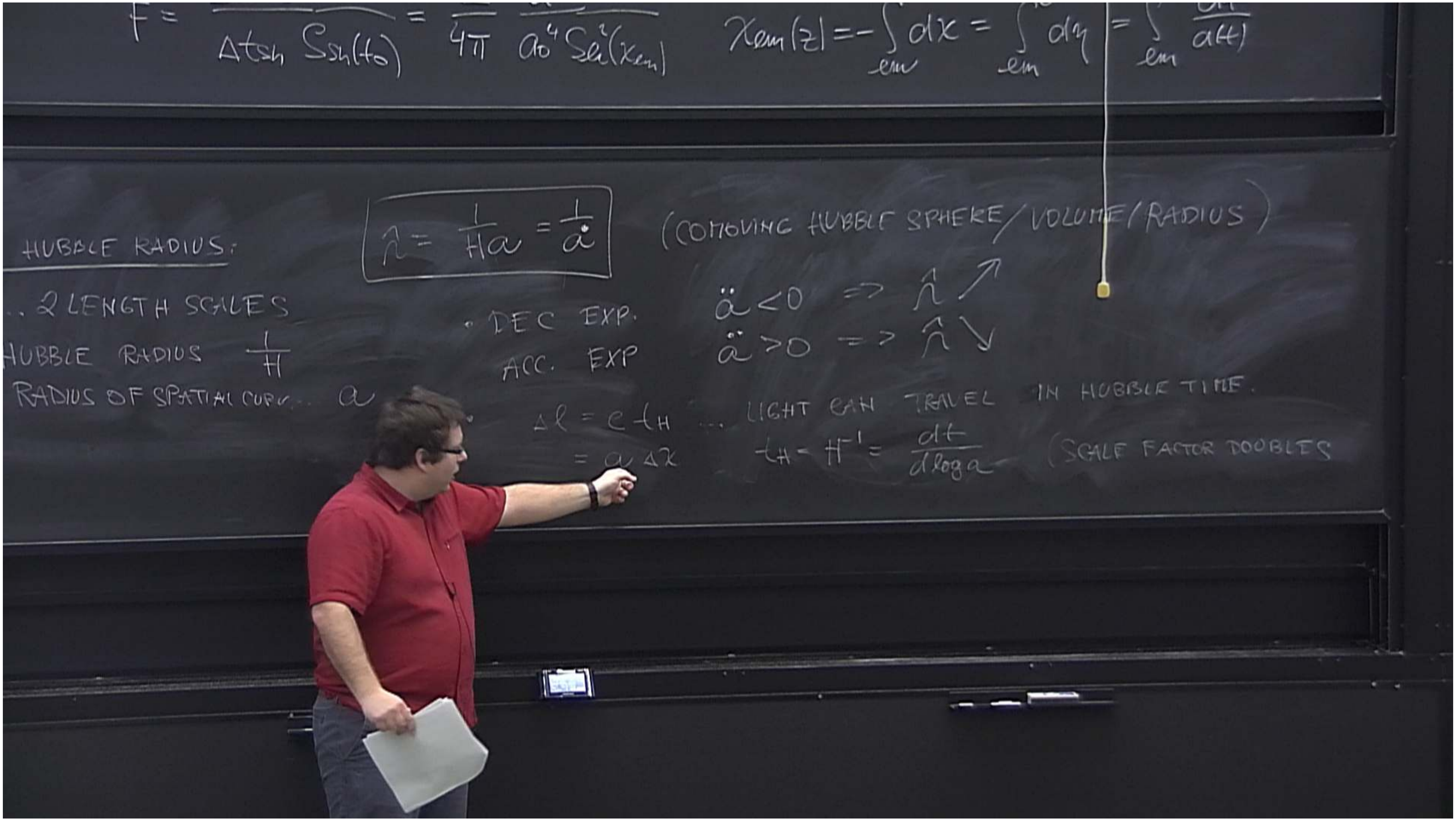

MOVING HUBBLE RADIUS:
FRW ... 2 LENGTH SCALE
HUBBLE RADIUS
RADIUS OF SPATI
(COMOVING HUBBLE SPHERE/VOLUME/RADIUS)



TION
MOVING HUBBLE RADIUS:
$\lambda = \frac{1}{Ha} = \frac{1}{\dot{a}}$
(COMOVING HUBBLE SPHERE/VOLUME/RADIUS)
FRW ... 2 LENGTH SCALES
HUBBLE RADIUS $\frac{1}{H}$
RADIUS OF SPATIAL CURV... a


g) INFLATION
• COMOVING HUBBLE RADIUS:
FRW ... 2 LENGTH SCALES
HUBBLE RADIUS 1/H
RADIUS OF SPATIAL CURV. ... a
r̂ = 1/Ha = 1/ȧ
(COMOVING HUBBLE SPHERE/VOLUME/RA
• DEC EXP. ä < 0 => r̂ ↗
ACC. EXP ä > 0 => r̂ ↘
Δl = c t_H ...


HUBBLE RADIUS:
(COMOVING HUBBLE SPHERE / VOLUME / RADIUS)
.. 2 LENGTH SCALES
HUBBLE RADIUS
RADIUS OF SPATIAL CURV.
DEC EXP.
ACC. EXP
LIGHT CAN TRAVEL IN HUBBLE TIME.
(SCALE FACTOR DOUBLES

$$F = \frac{\ldots}{\Delta t_{sh}\, S_{sh}(t_0)} = \frac{\ldots}{4\pi} \, \frac{\ldots}{a_0^4\, S_k^2(\chi_{em})} \qquad \chi_{em}(z) = -\int_{em} d\chi = \int_{em} d\eta = \int_{em} \frac{dt}{a(t)}$$

HUBBLE RADIUS:

... 2 LENGTH SCALES

HUBBLE RADIUS $\frac{1}{H}$

RADIUS OF SPATIAL CURV... a

$$\boxed{\hat{r} = \frac{1}{Ha} = \frac{1}{\dot{a}}}$$

(COMOVING HUBBLE SPHERE/VOLUME/RADIUS)

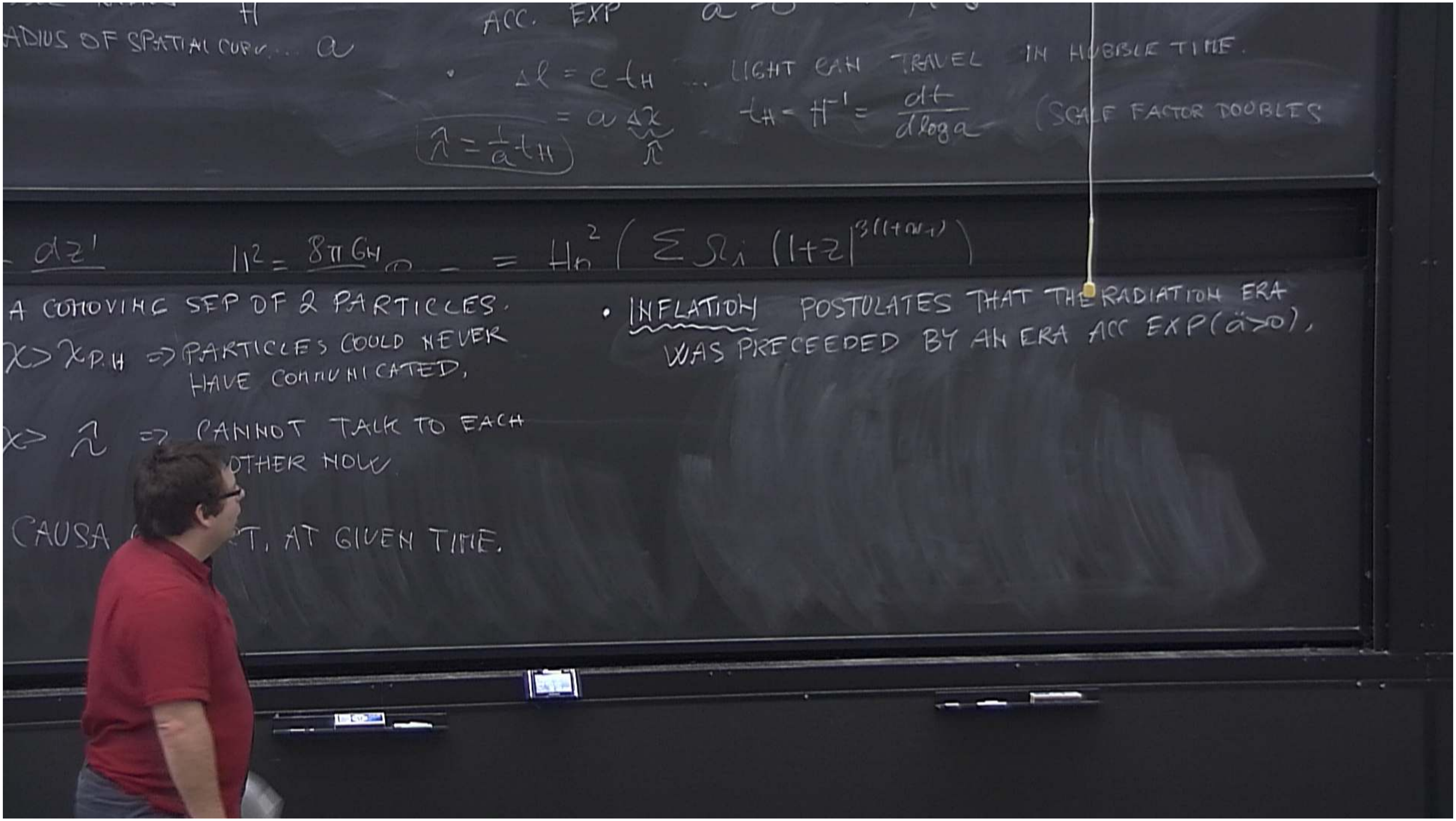
• DEC EXP. $\ddot{a} < 0 \Rightarrow \hat{r} \nearrow$

ACC. EXP $\ddot{a} > 0 \Rightarrow \hat{r} \searrow$

• $\Delta l = c\, t_H$ ... LIGHT CAN TRAVEL IN HUBBLE TIME.

$= a \underbrace{\Delta x}_{\hat{r}}$ $\quad t_H = H^{-1} = \frac{dt}{d\log a}$ (SCALE FACTOR DOUBLES

$\hat{r} = \frac{1}{a} t_H$


ADIUS OF SPATIAL CURV... a
ACC. EXP
Δl = c t_H ... LIGHT CAN TRAVEL IN HUBBLE TIME.
= a Δx
t_H = H^-1 = dt / d log a
(SCALE FACTOR DOUBLES
λ = 1/a t_H
H^2 = 8πG/3 ρ = H_0^2 (Σ Ω_i (1+z)^3(1+w_i))
A COMOVING SEP OF 2 PARTICLES.
x > x_P.H => PARTICLES COULD NEVER HAVE COMMUNICATED.
x > λ => CANNOT TALK TO EACH OTHER NOW
CAUSA ... T, AT GIVEN TIME.
• INFLATION POSTULATES THAT THE RADIATION ERA WAS PRECEEDED BY AN ERA ACC EXP (ä>0).

LET x BE A COMOVING SEP OF 2 PARTICLES.

$\Rightarrow$ IF $x > x_{P.H}$ $\Rightarrow$ PARTICLES COULD NEVER HAVE COMMUNICATED.

IF $x > \hat{r}$ $\Rightarrow$ CANNOT TALK TO EACH OTHER NOW

$\hat{r}$ ... CAUSA CONTACT, AT GIVEN TIME.

• INFLATION POSTULATES THAT THE RADIAT
WAS PRECEEDED BY AN ERA ACC EX

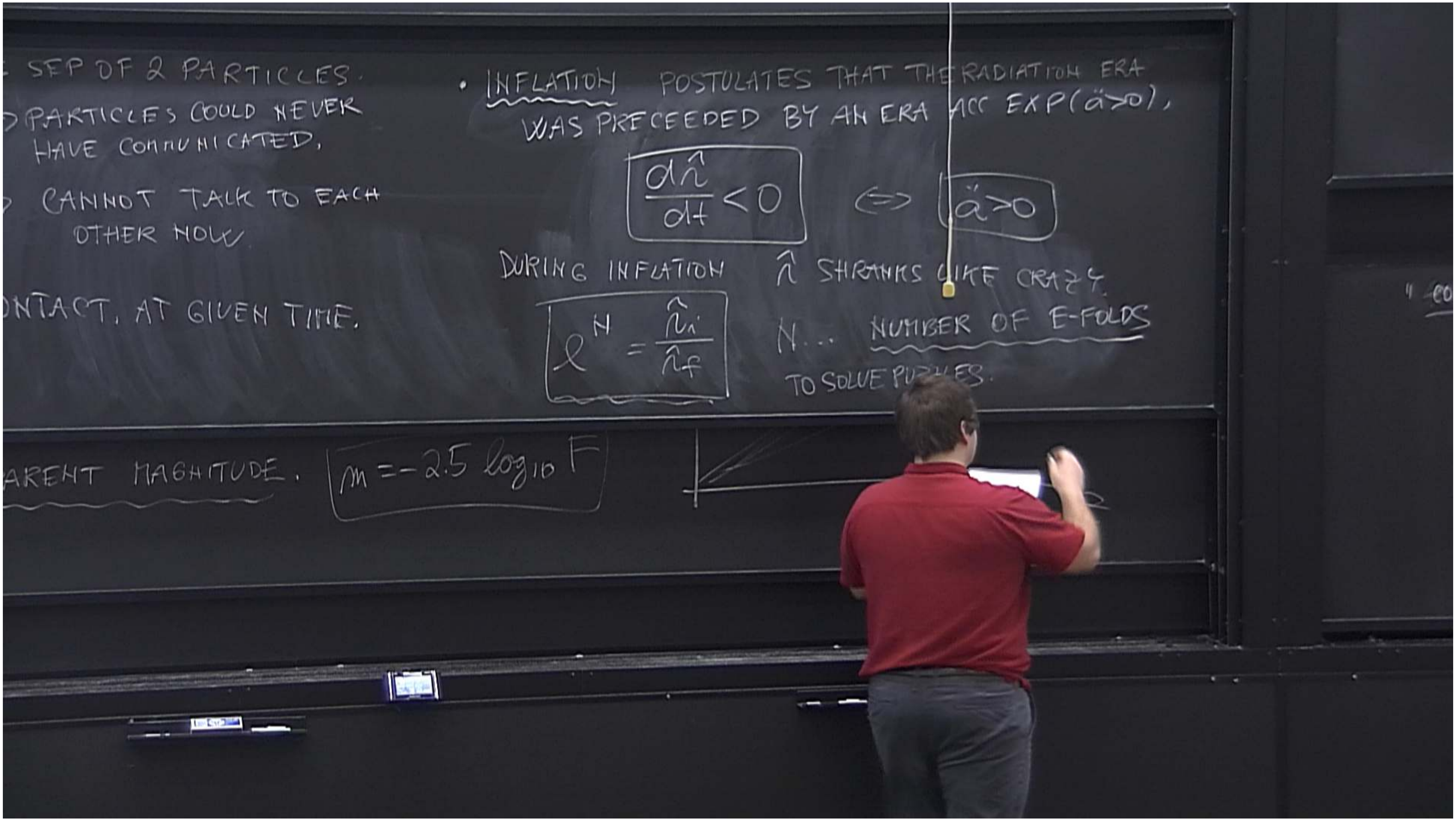
$$\boxed{\frac{d\hat{r}}{dt} < 0} \iff \boxed{\ddot{a} > 0}$$

DURING INFLATION $\hat{r}$ SHRINKS LIKE CRA

$$\boxed{e^{N} = \frac{\hat{r}_i}{\hat{r}_f}}$$

N ... NUMBER OF

• APPARENT MAGNITUDE. $\boxed{m = -2.5 \log_{10} F}$


SEP OF 2 PARTICLES.
PARTICLES COULD NEVER HAVE COMMUNICATED.
CANNOT TALK TO EACH OTHER NOW
ONTACT, AT GIVEN TIME.
INFLATION POSTULATES THAT THE RADIATION ERA WAS PRECEEDED BY AN ERA ACC EXP($\ddot{a}>0$).
$\frac{d\hat{r}}{dt}<0 \Leftrightarrow \ddot{a}>0$
DURING INFLATION $\hat{r}$ SHRINKS LIKE CRAZY.
$e^N = \frac{\hat{r}_i}{\hat{r}_f}$
N... NUMBER OF E-FOLDS
TO SOLVE PUZZLES.
ARENT MAGNITUDE.
$m = -2.5 \log_{10} F$