Title: PSI 2015/2016 Explorations in Cosmology - Kendrick Smith - 1

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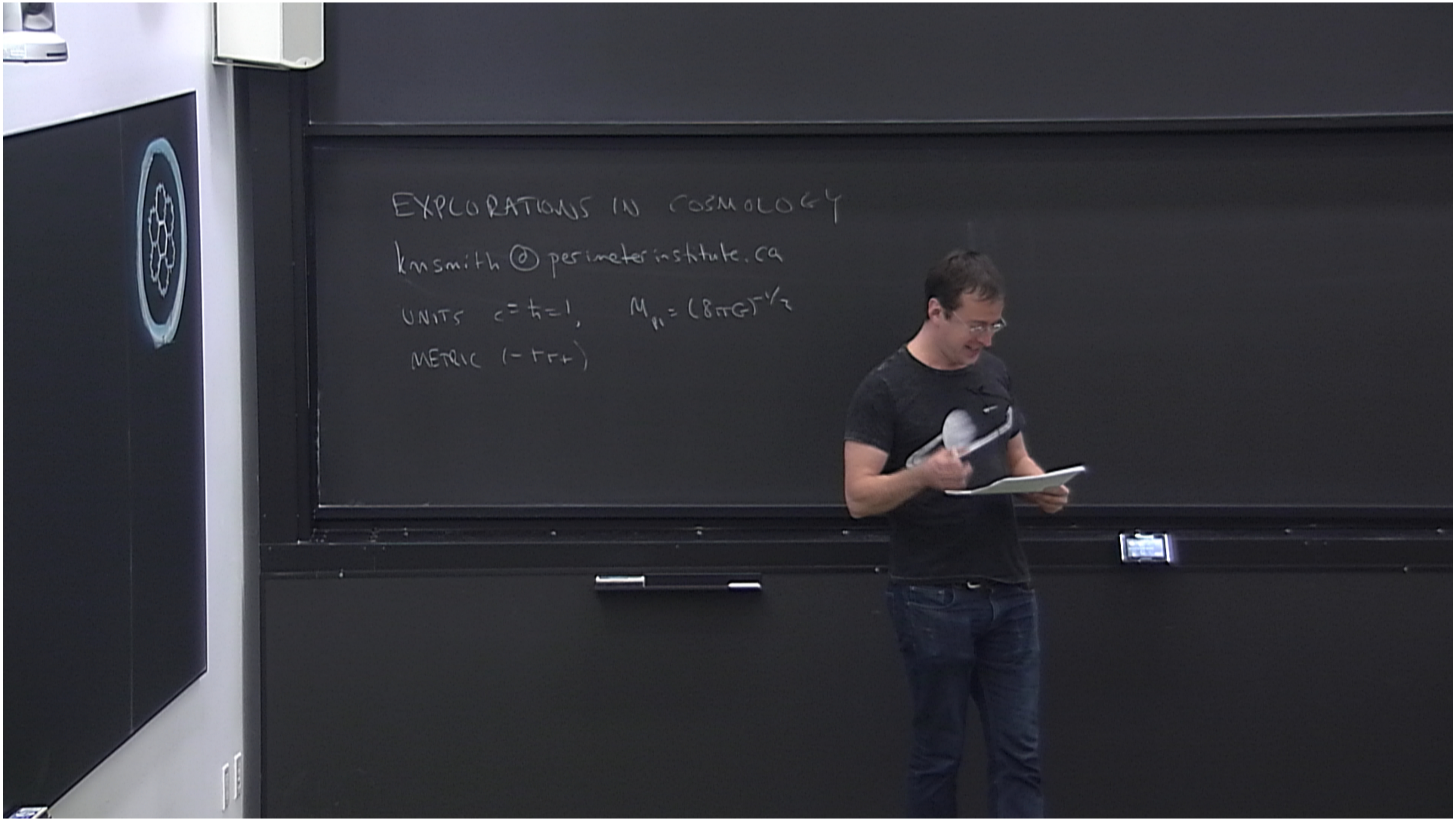
Abstract:


EXPLORATIONS IN COSMOLOGY
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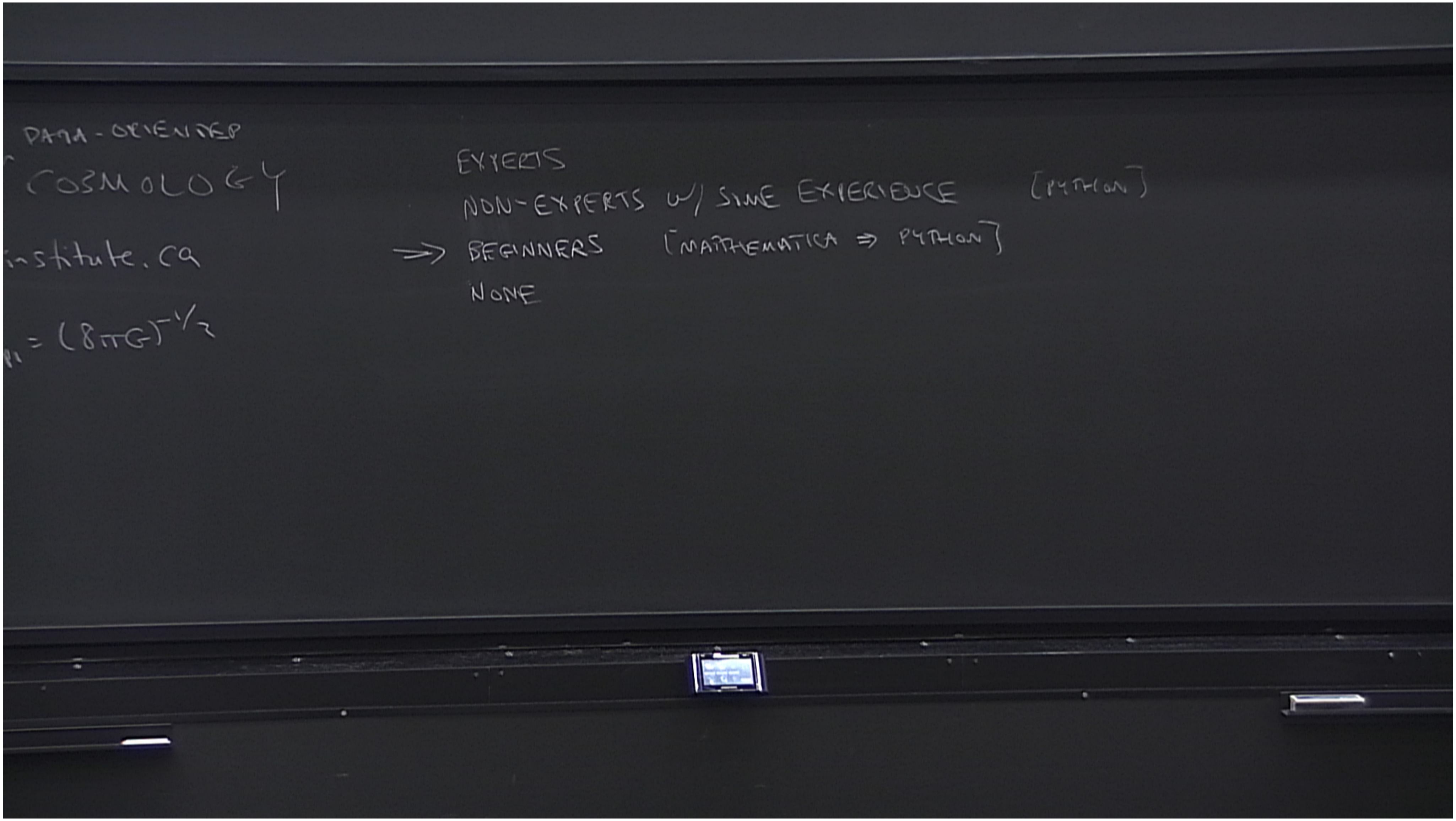
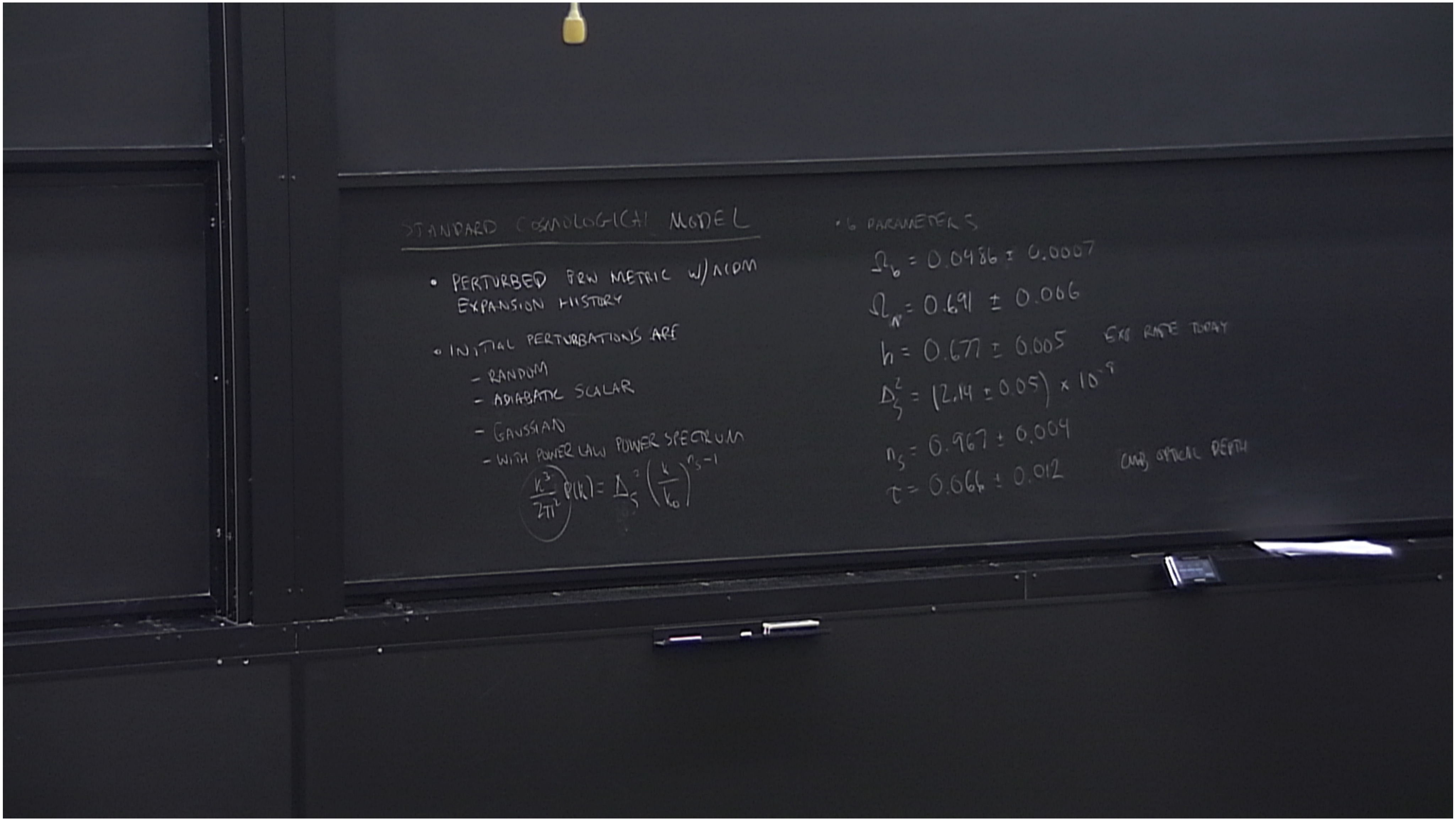
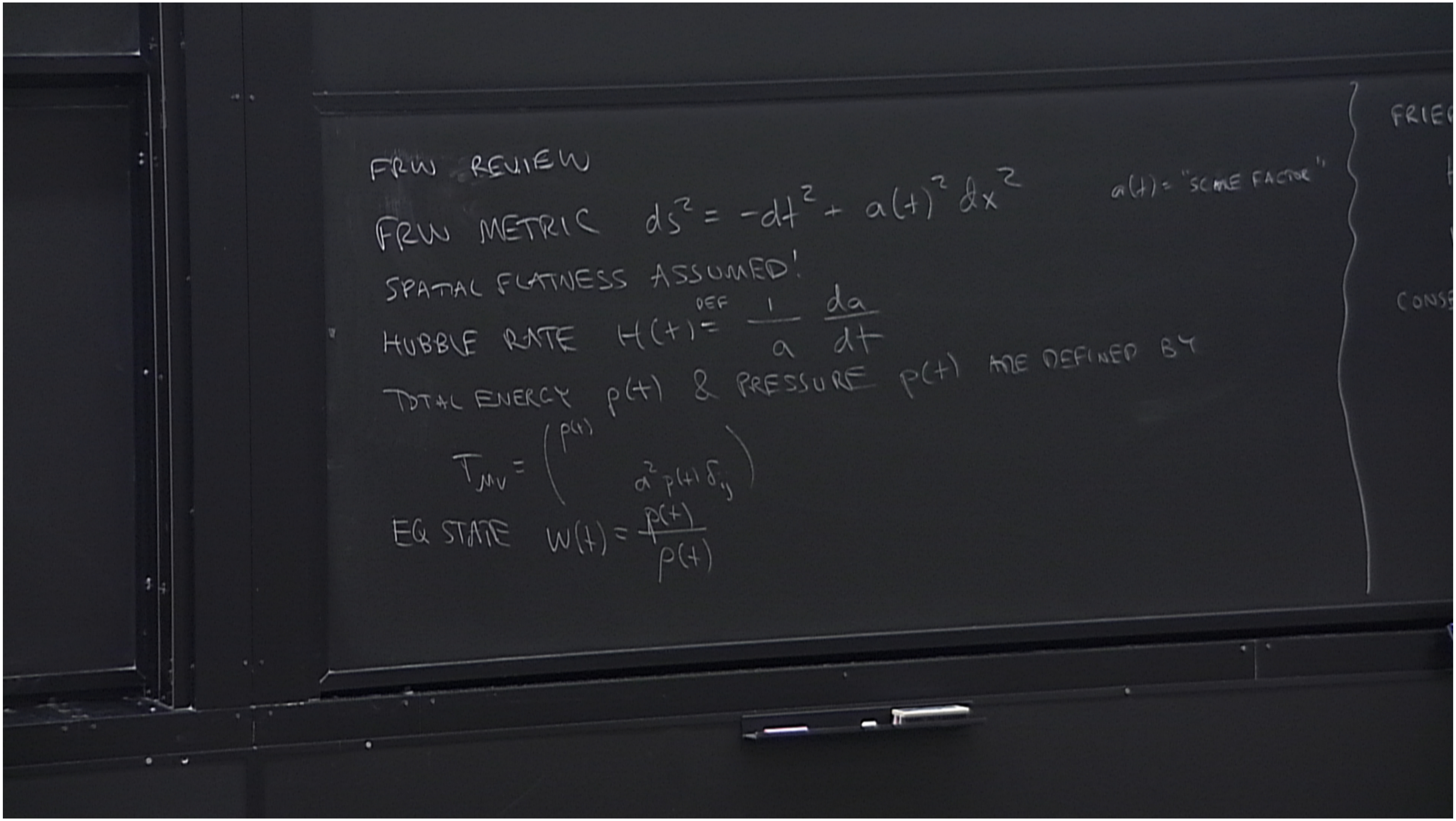
UNITS c = ħ = 1, $M_{pl} = (8\pi G)^{-1/2}$
METRIC (− + + +)


DATA-ORIENTED
COSMOLOGY
institute.ca
$= (8\pi G)^{-1/2}$
EXPERTS
NON-EXPERTS w/ SOME EXPERIENCE [PYTHON]
⇒ BEGINNERS [MATHEMATICA ⇒ PYTHON]
NONE



STANDARD COSMOLOGICAL MODEL
• PERTURBED FRW METRIC W/ ΛCDM EXPANSION HISTORY
• INITIAL PERTURBATIONS ARE
- RANDOM
- ADIABATIC SCALAR
- GAUSSIAN
- WITH POWER LAW POWER SPECTRUM
$\frac{k^3}{2\pi^2} P(k) = \Delta_s^2 \left(\frac{k}{k_0}\right)^{n_s - 1}$
• 6 PARAMETERS
$\Omega_b = 0.0486 \pm 0.0007$
$\Omega_\Lambda = 0.691 \pm 0.006$
$h = 0.677 \pm 0.005$
EXP RATE TODAY
$\Delta_s^2 = (2.14 \pm 0.05) \times 10^{-9}$
$n_s = 0.967 \pm 0.004$
$\tau = 0.066 \pm 0.012$
CMB OPTICAL DEPTH


FRW REVIEW
FRW METRIC $ds^2 = -dt^2 + a(t)^2 dx^2$
$a(t)$ = "SCALE FACTOR"
SPATIAL FLATNESS ASSUMED!
HUBBLE RATE $H(t) \overset{DEF}{=} \frac{1}{a}\frac{da}{dt}$
TOTAL ENERGY $\rho(t)$ & PRESSURE $p(t)$ ARE DEFINED BY
$T_{\mu\nu} = \begin{pmatrix} \rho(t) & \\ & a^2 p(t)\delta_{ij} \end{pmatrix}$
EQ STATE $w(t) = \frac{p(t)}{\rho(t)}$

EXAMPLE: ΛCDM UNIVERSE

(NON-REL.)

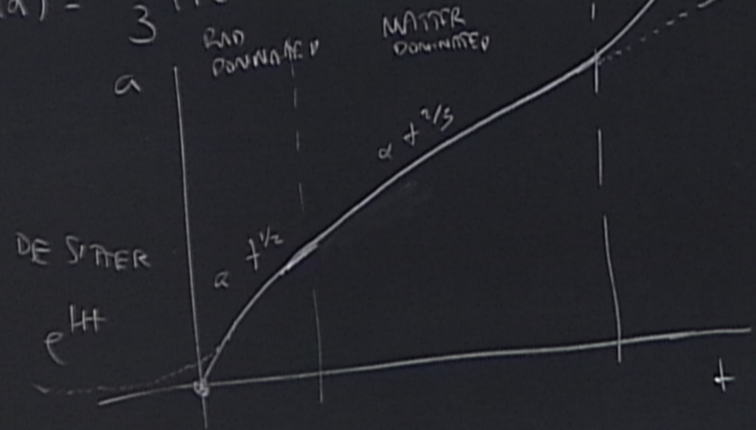
TOTAL STRESS ENERGY IS SUM OF INDEPENDENT RADIATION + MATTER + C.C.

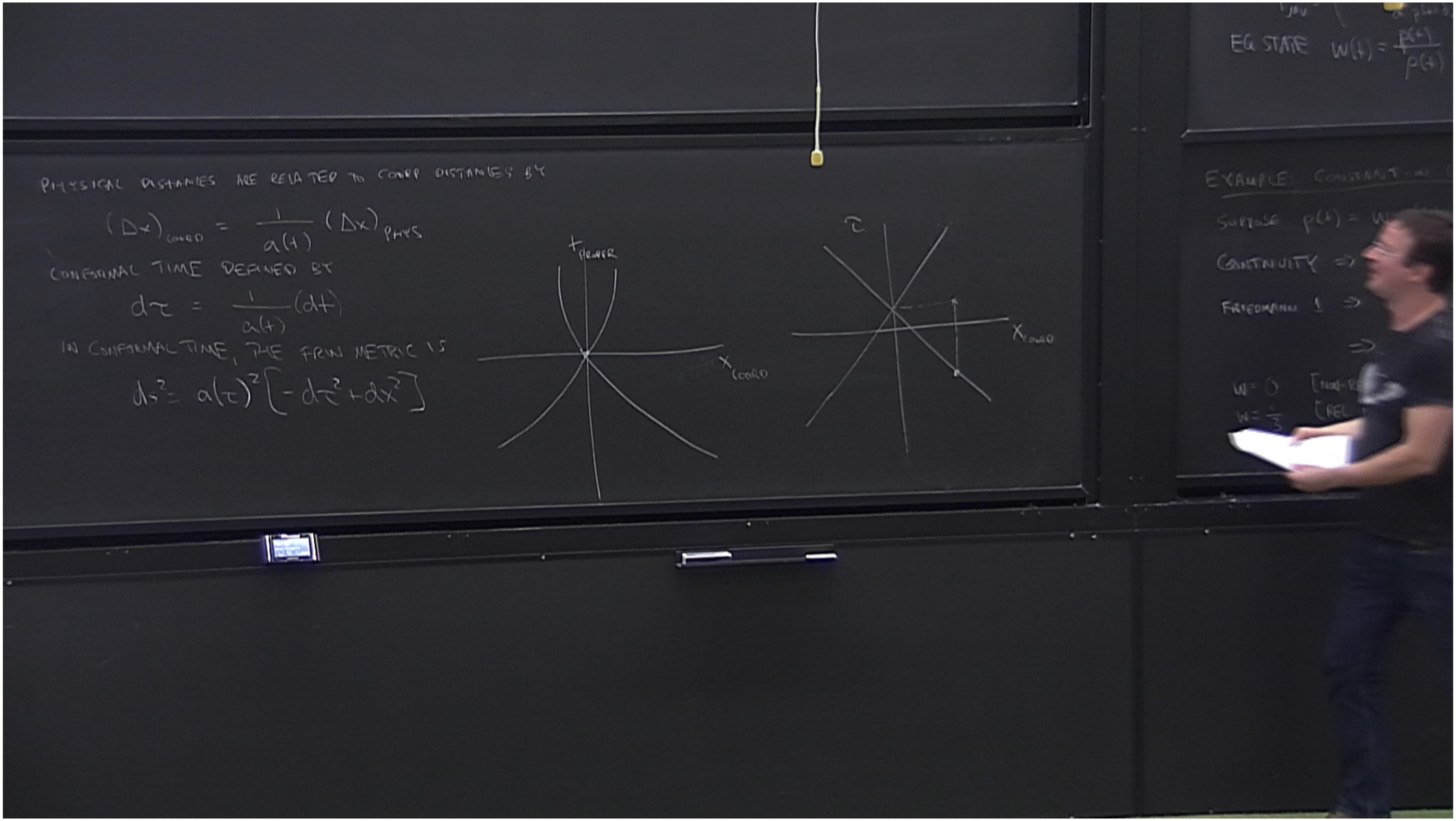
$$\rho(a) = \rho_{r0}\, a^{-4} + \rho_{m0}\, a^{-3} + \Lambda$$

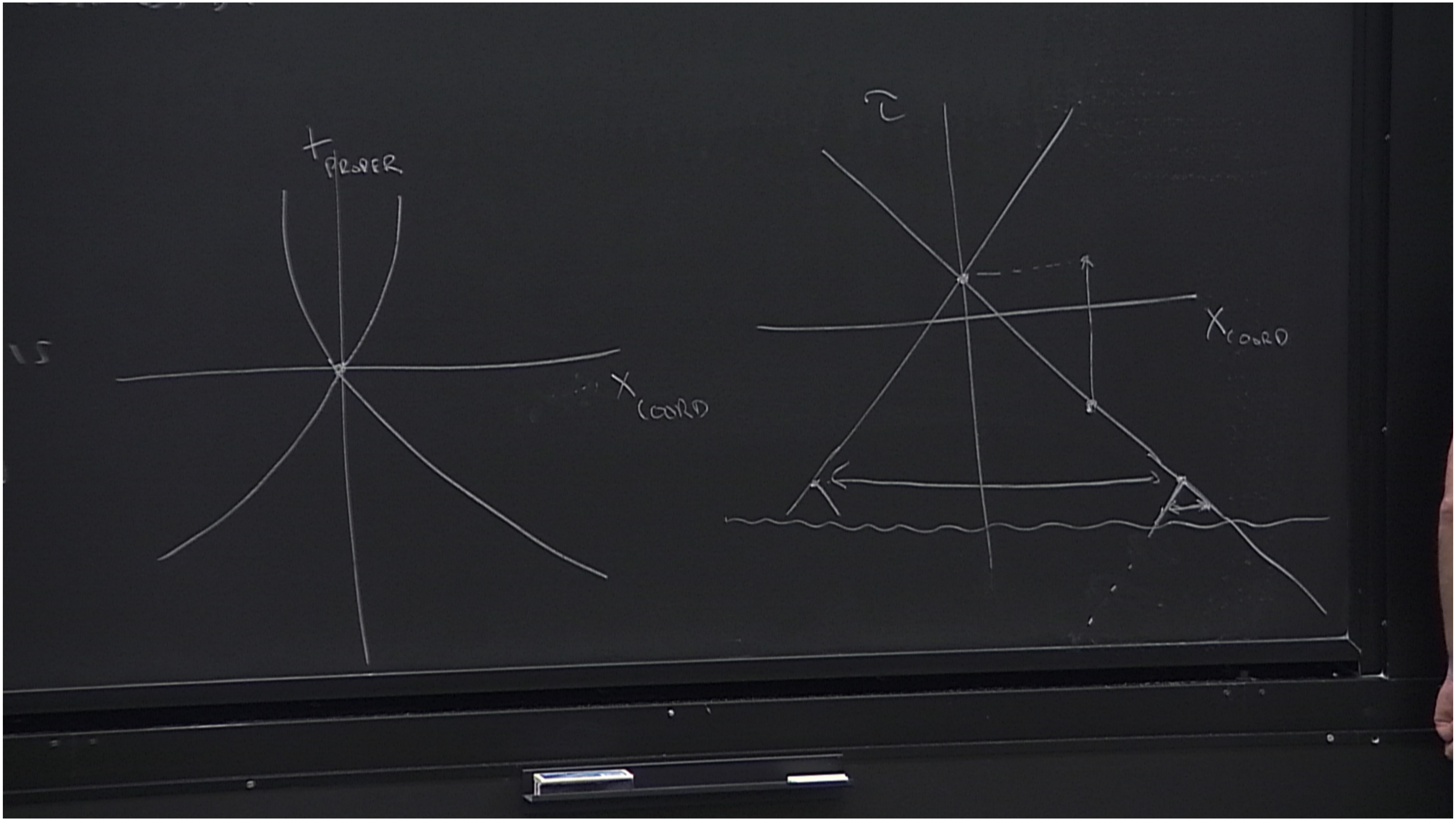
$\Lambda \rightarrow$ INDEP. OF a

$$p(a) = \frac{1}{3}\rho_{r0}\, a^{-4} - \Lambda$$

e^{Ht} "DE SITTER"




PHYSICAL DISTANCES ARE RELATED TO COORD DISTANCES BY
$(\Delta x)_{coord} = \frac{1}{a(t)} (\Delta x)_{phys}$
CONFORMAL TIME DEFINED BY
$d\tau = \frac{1}{a(t)} (dt)$
IN CONFORMAL TIME, THE FRW METRIC IS
$ds^2 = a(\tau)^2 \left[-d\tau^2 + dx^2 \right]$
t_{proper}
x_{coord}
τ
x_{coord}
EQ STATE $w(t) = \frac{p(t)}{\rho(t)}$
EXAMPLE:
CONTINUITY ⇒
FRIEDMANN ⇒



t PROPER
X COORD
τ
X COORD

IS CONF. TIME FINITE IN THE PAST? $\int d\tau = \int \frac{dt}{a(t)}$

- ASSUMING RAD DOM? $\int \frac{dt}{t^{1/2}}$
- ASSUMING INFLATION? $\int \frac{dt}{e^{Ht}} = \infty$

IN THE FUTURE?

- ASSUMING MATTER DOM? $\int^{\infty} \frac{dt}{t^{2/3}} = \infty$
- ASSUMING C.C.? $\int^{\infty} \frac{dt}{e^{Ht}} < \infty$

FRIEDMANN'S EQUATIONS

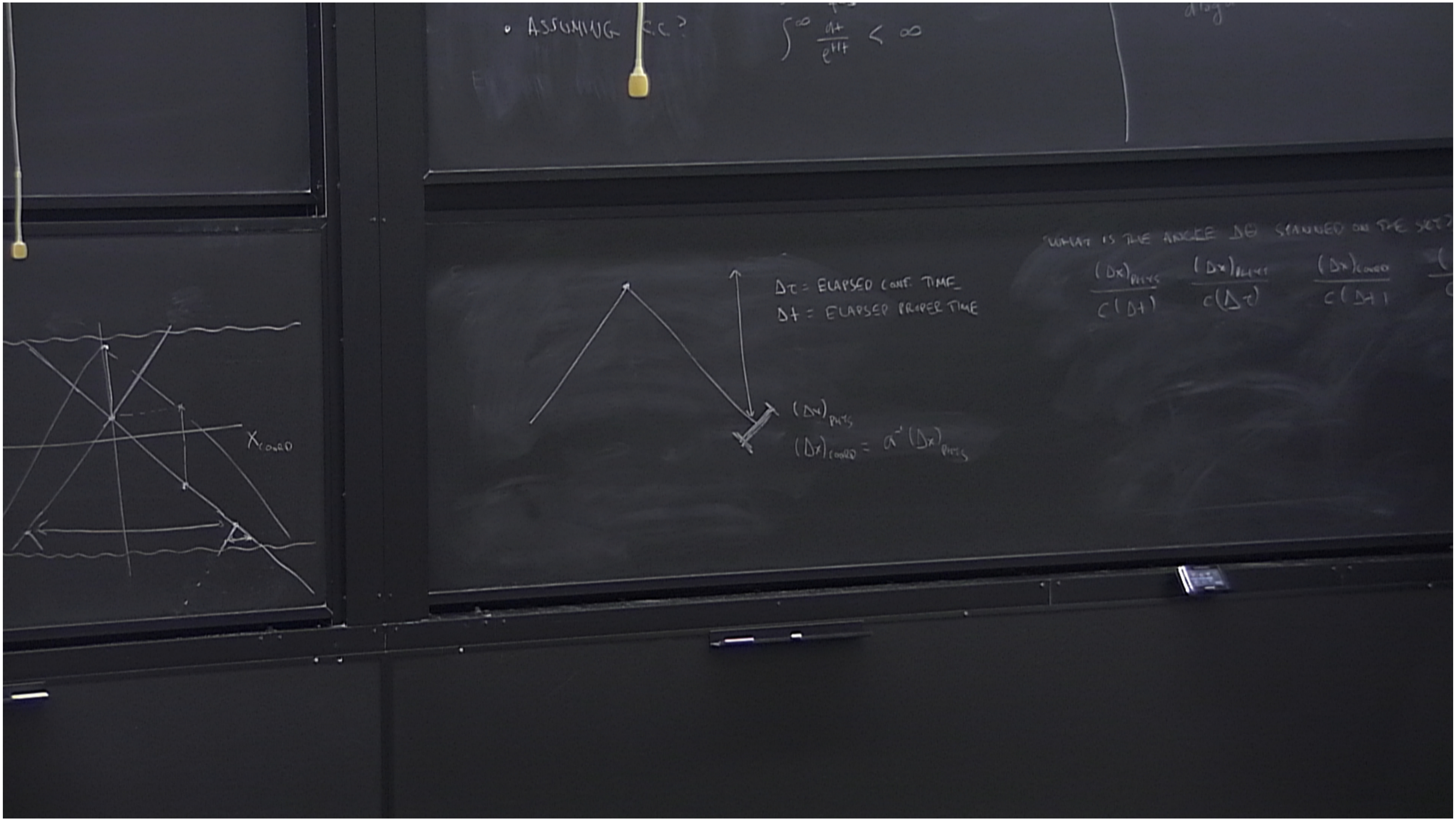
$$H^2 = \frac{8\pi G}{3}\rho$$

$$\dot{H} = -4\pi G(\rho + p)$$

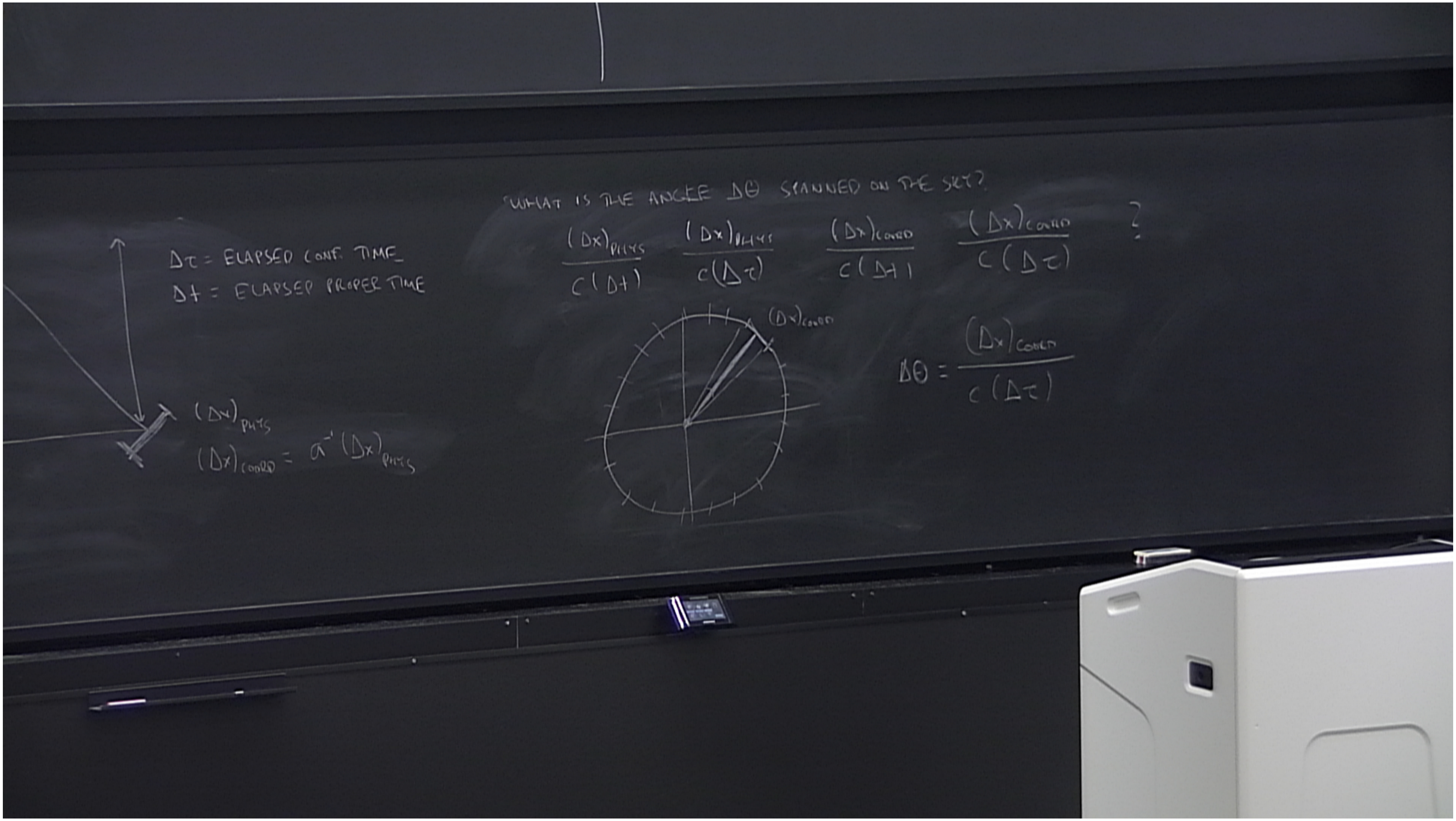
CONSEQUENCE: CONTINUITY EQ

$$\frac{d\log\rho}{d\log a} = -3(1+w)$$

$$\nabla_\mu T^{\mu\nu} = 0 \qquad \nabla_\mu G^{\mu\nu} = 0$$



• ASSUMING C.C ?
$\int^{\infty} \frac{dt}{e^{Ht}} < \infty$
WHAT IS THE ANGLE Δθ SPANNED ON THE SKY?
$\frac{(\Delta x)_{PHYS}}{c(\Delta t)}$ $\frac{(\Delta x)_{PHYS}}{c(\Delta \tau)}$ $\frac{(\Delta x)_{COORD}}{c(\Delta t)}$
Δτ = ELAPSED CONF. TIME
Δt = ELAPSED PROPER TIME
$(\Delta x)_{PHYS}$
$(\Delta x)_{COORD} = a^{-1} (\Delta x)_{PHYS}$
X_{COORD}


WHAT IS THE ANGLE $\Delta\theta$ SPANNED ON THE SKY?
$\Delta\tau$ = ELAPSED CONF. TIME
Δt = ELAPSED PROPER TIME
$\frac{(\Delta x)_{PHYS}}{c(\Delta t)}$
$\frac{(\Delta x)_{PHYS}}{c(\Delta \tau)}$
$\frac{(\Delta x)_{COORD}}{c(\Delta t)}$
$\frac{(\Delta x)_{COORD}}{c(\Delta \tau)}$
?
$(\Delta x)_{COORD}$
$\Delta\theta = \frac{(\Delta x)_{COORD}}{c(\Delta \tau)}$
$(\Delta x)_{PHYS}$
$(\Delta x)_{COORD} = a^{-1} (\Delta x)_{PHYS}$