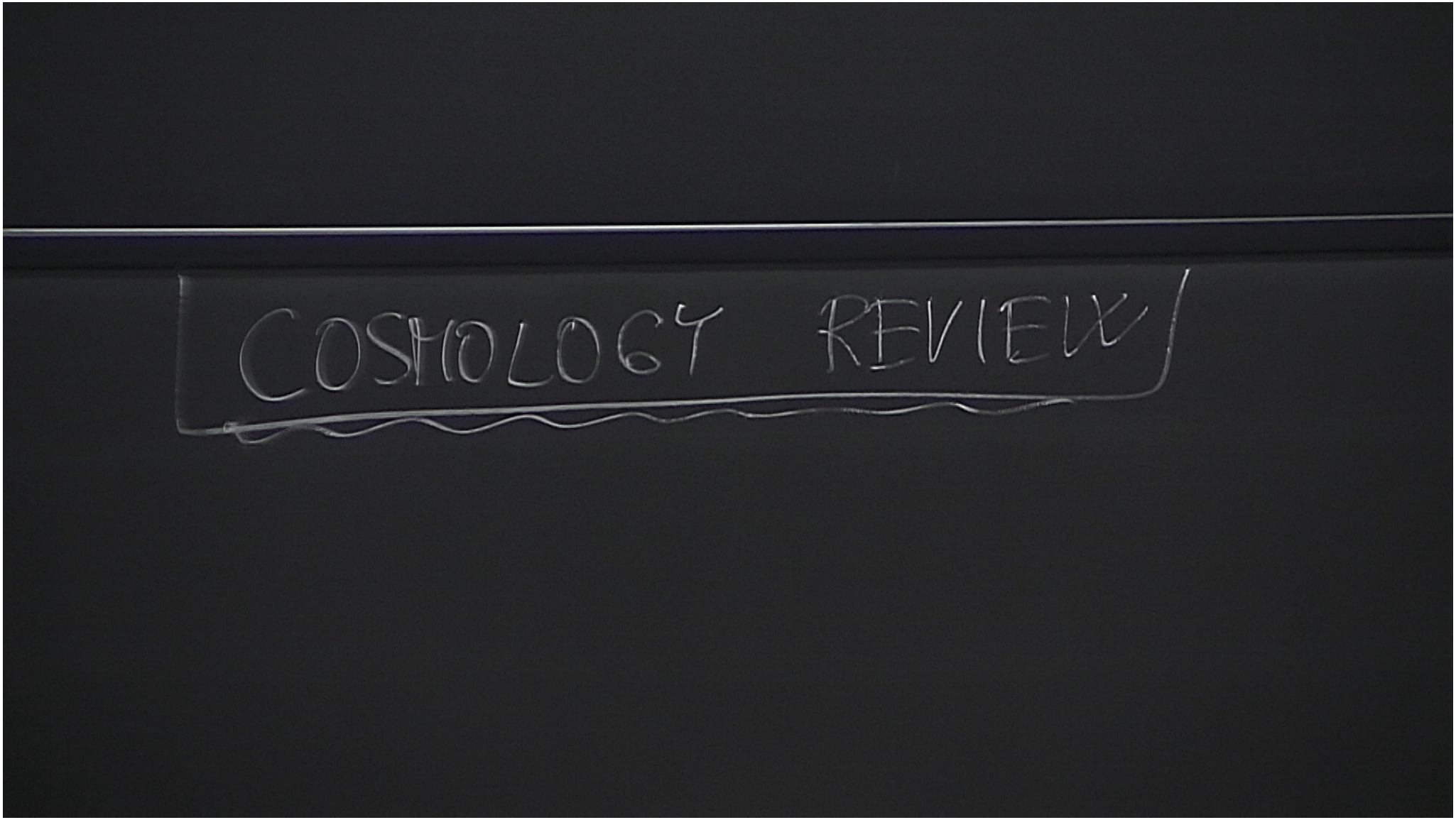
Title: PSI 17/18 - Cosmology - Lecture 1

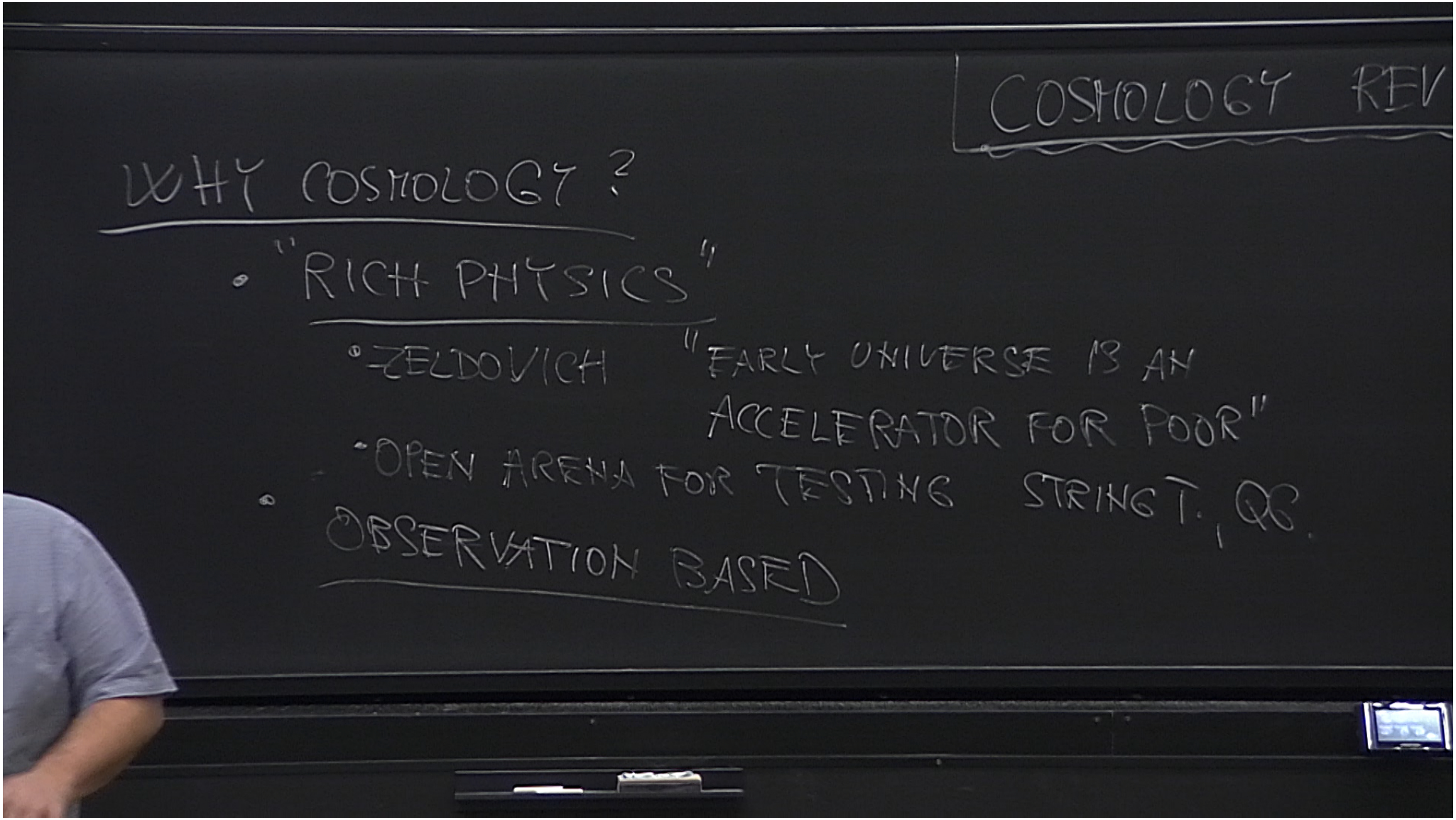
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URL: http://pirsa.org/18010051

Abstract:


COSMOLOGY REVIEW



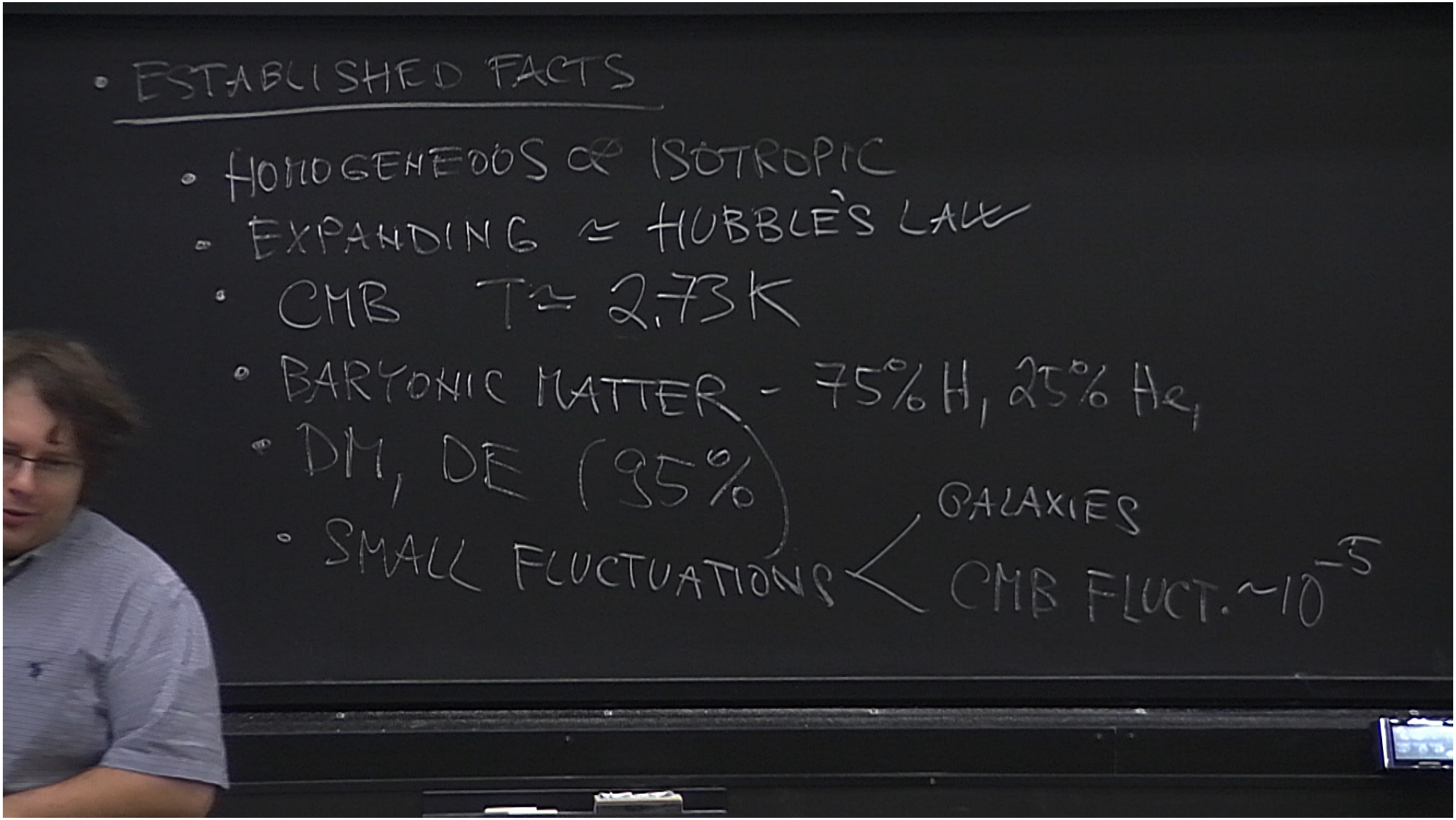

COSMOLOGY REV
WHY COSMOLOGY ?
"RICH PHYSICS"
ZELDOVICH "EARLY UNIVERSE IS AN ACCELERATOR FOR POOR"
OPEN ARENA FOR TESTING STRING T., QG.
OBSERVATION BASED

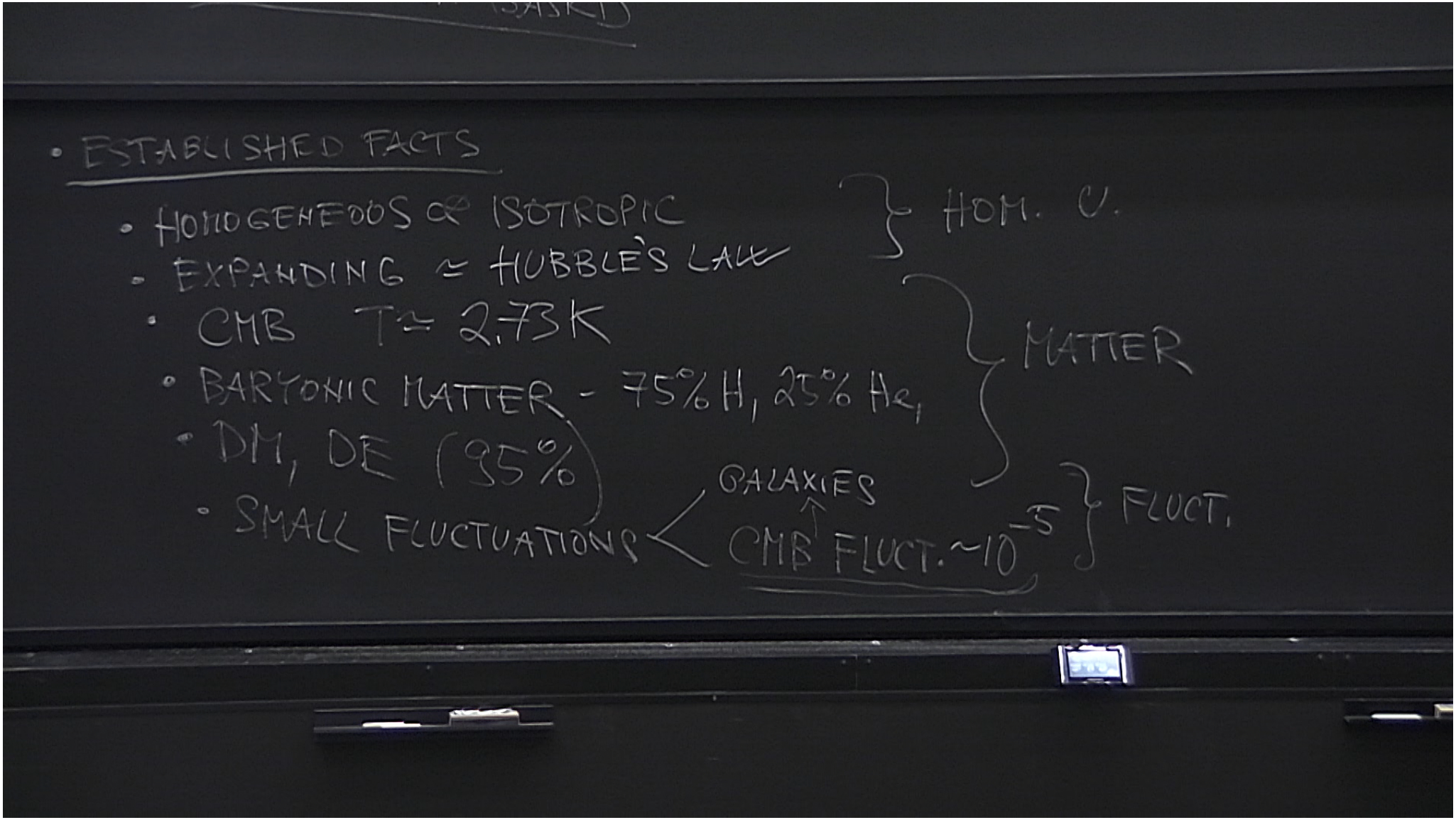
- NEW PHYSICS LIKELY TO BE DISCOVERED.

  Δ-PROBLEM, η-PROBLEM, ζ_i-PROBLEM.

  ALL PROBLEMS WITH INFLATION

- JOBS


• ESTABLISHED FACTS
• HOMOGENEOUS & ISOTROPIC
• EXPANDING ≃ HUBBLE'S LAW
• CMB T≃ 2.73K
• BARYONIC MATTER - 75% H, 25% He,
• DM, DE (95%)
• SMALL FLUCTUATIONS < GALAXIES
CMB FLUCT. ~ 10^{-5}


ESTABLISHED FACTS
HOMOGENEOUS & ISOTROPIC
EXPANDING ≃ HUBBLE'S LAW
HOM. U.
CMB T ≃ 2.73K
BARYONIC MATTER - 75% H, 25% He,
DM, DE (95%)
MATTER
SMALL FLUCTUATIONS
GALAXIES
CMB FLUCT. ~ 10^{-5}
FLUCT.

CHAPTER I: HOMOGENEOUS UNIVERSE

- OBSERVABLE U 3×10^4 Mpc
- HOM & ISOTROPIC ~ SCALES 100 Mpc.
- ISOTROPY .. WE OBSERVE.

COPERNICUS COSMOLOGICAL P. => EVERY OBSERVER IN U. SEES THE SAME.

U.

ATTER

} FLUCT.


EXIT

CHAPTER I: HOMOGENEOUS UNIVERSE

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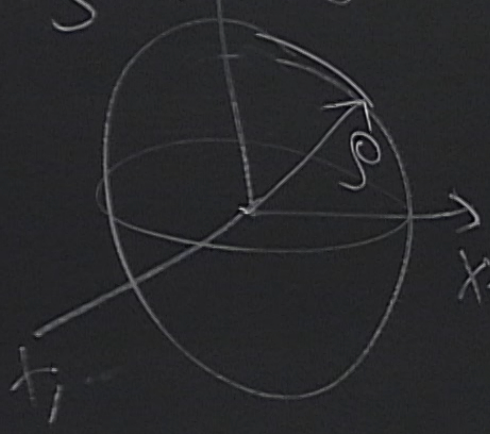
T.

=> HOMOGENEITY

(ALL HOM & ISOTROPIC SPACES)

CONSTRUCTION: EMBEDDING IN $(n+1)$-DIM SPACE.

EX 1: S^2



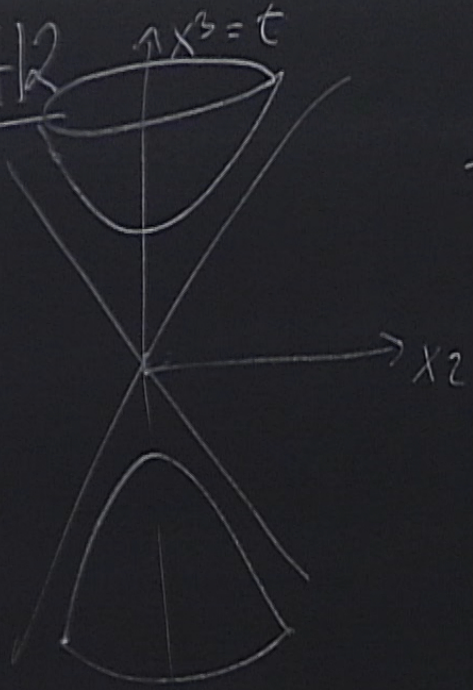
EUCL: $ds^2 = (dx^1)^2 + (dx^2)^2 + (dx^3)^2$

EMB: $S^2 = (x^1)^2 + (x^2)^2 + (x^3)^2$

$$0 = x^1 dx^1 + x^2 dx^2 + x^3 dx^3$$

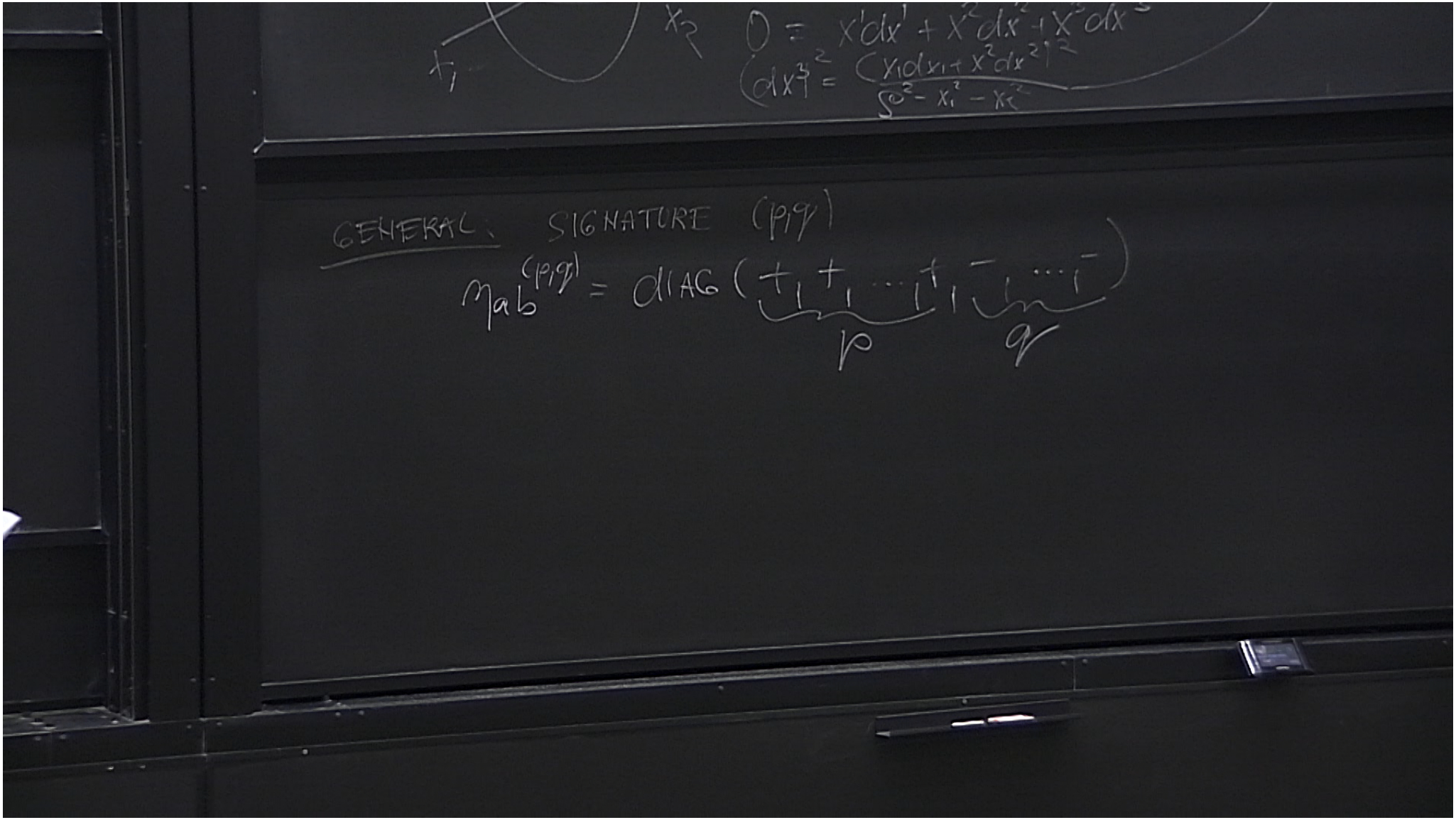
$$(dx^3)^2 = \frac{(x_1 dx_1 + x^2 dx^2)^2}{S^2 - x_1^2 - x_2^2}$$

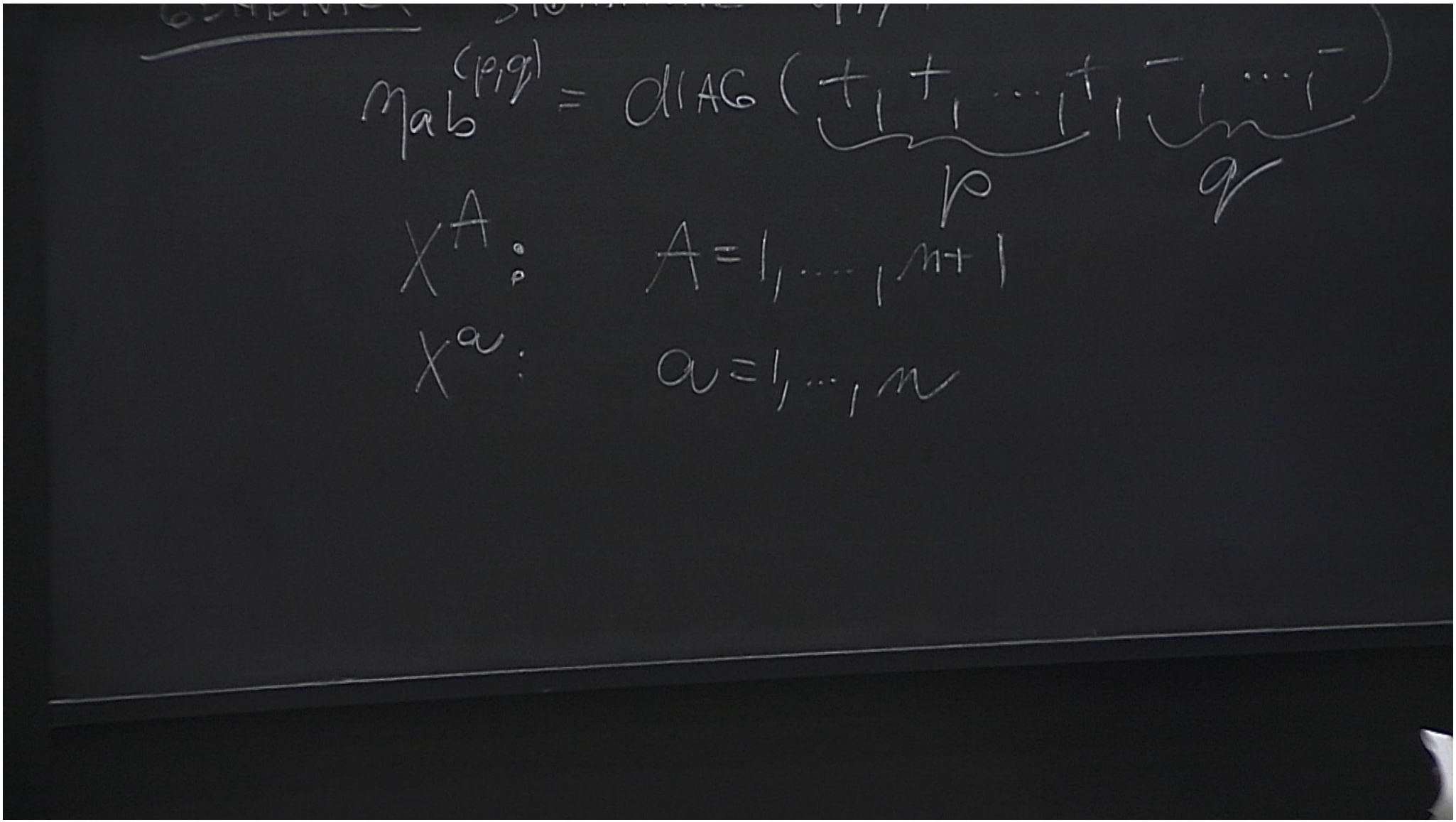
EX2 : H^2



MINK: $ds^2 = (dx^1)^2 + (dx^2)^2 - (dx^3)^2$

EMB: $-S^2 = (X^1)^2 + (X^2)^2 - (X^3)^2$


x_2
$0 = x^1dx^1 + x^2dx^2 + x^3dx^3$
$(dx^3)^2 = \frac{(x_1dx_1 + x^2dx^2)^2}{s^2 - x_1^2 - x_2^2}$
GENERAL SIGNATURE (p,q)
$\eta_{ab}^{(p,q)} = \mathrm{DIAG}(\underbrace{+,+,\cdots,+}_{p},\underbrace{-,\cdots,-}_{q})$


$\eta_{ab}^{(p,q)} = \mathrm{diag}(\underbrace{+,+,\cdots,+}_{p},\underbrace{-,\cdots,-}_{q})$
X^A: $A = 1, \ldots, n+1$
X^a: $a = 1, \ldots, n$

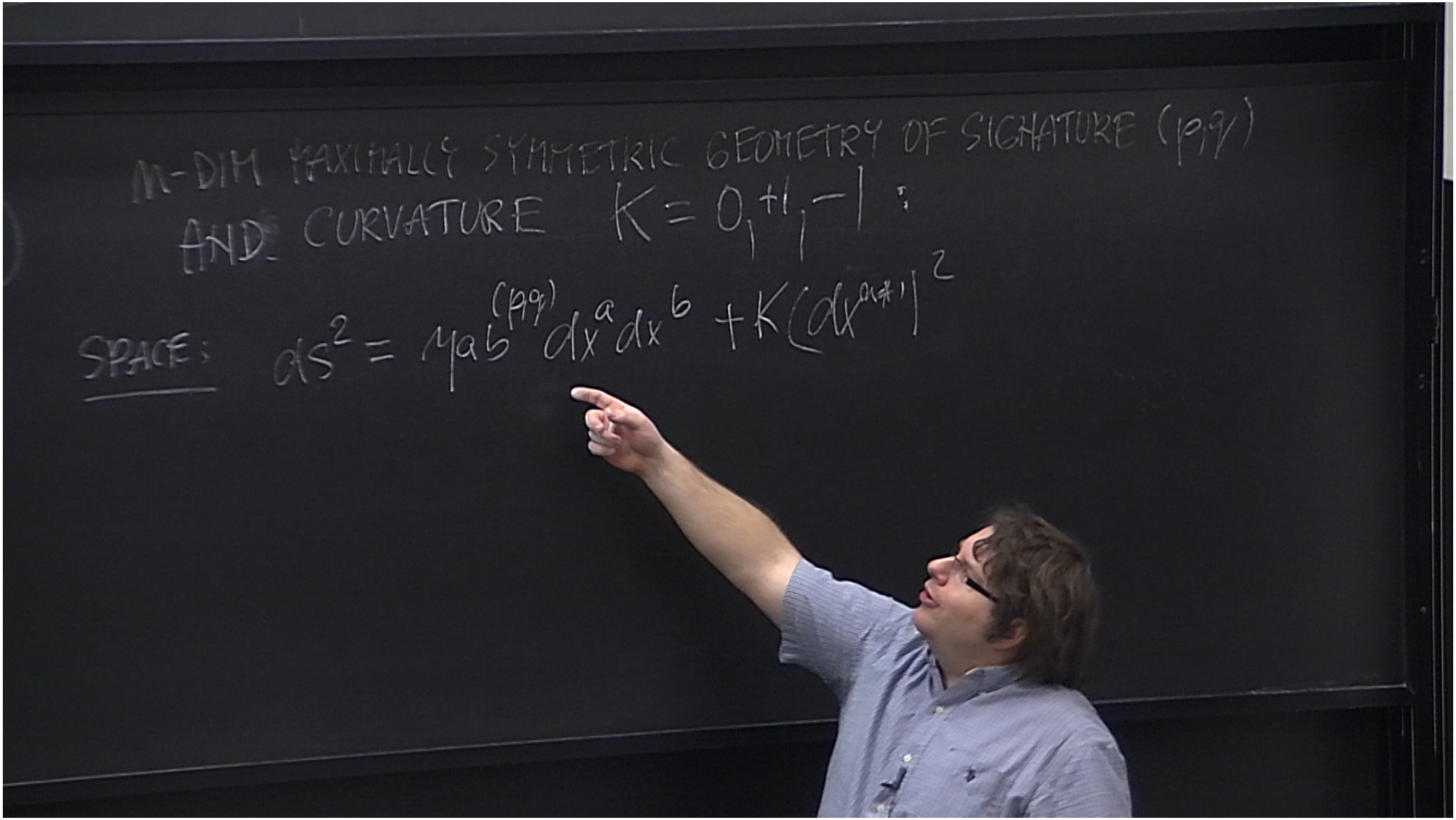
GENERAL: SIGNATURE (p,q)

$$\eta_{ab}^{(p,q)} = \mathrm{diag}(\underbrace{+,+,\dots,+}_{p},\underbrace{-,\dots,-}_{q})$$

X^A: $A = 1, \dots, n+1$

X^a: $a = 1, \dots, n$

$$X_a = \eta_{ab}^{(p,q)} X^b \quad , \quad X^2 = X_a X^a$$


n-DIM MAXIMALLY SYMMETRIC GEOMETRY OF SIGNATURE (p,q)
AND CURVATURE $K = 0, +1, -1$:
SPACE: $ds^2 = \gamma_{ab}^{(p,q)} dx^a dx^b + K(dx^{n+1})^2$

n-DIM MAXIMALLY SYMMETRIC GEOMETRY OF SIGNATURE (p,q)
AND CURVATURE $K = 0, +1, -1$:

SPACE: $ds^2 = \eta_{ab}^{(p,q)} dx^a dx^b + K(dx^{n+1})^2 = \eta_{AB}^{(p,q)K} dx^A dx^B$

CONSTR: $\eta_{AB}^{(p,q)K} x^A x^B = K s^2 \qquad (K \neq 0)$

$$K\rho^2 = K(x^{n+1})^2 + x^2$$

$$K x^{n+1} dx^{n+1} = -x_a dx^a$$

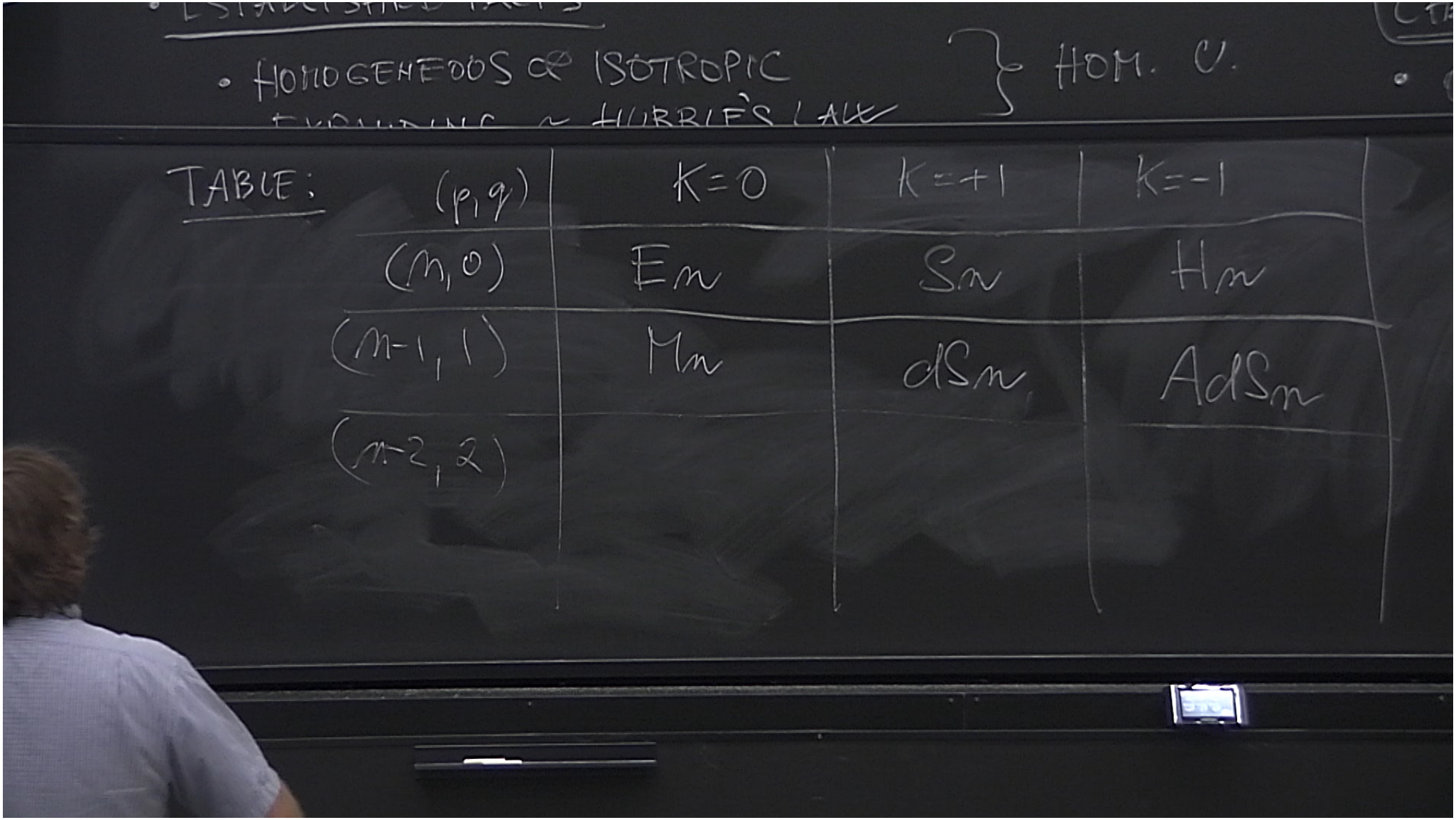
$$(dx^{n+1})^2 = \frac{(x_a dx^a)^2}{\rho^2 - Kx^2}$$

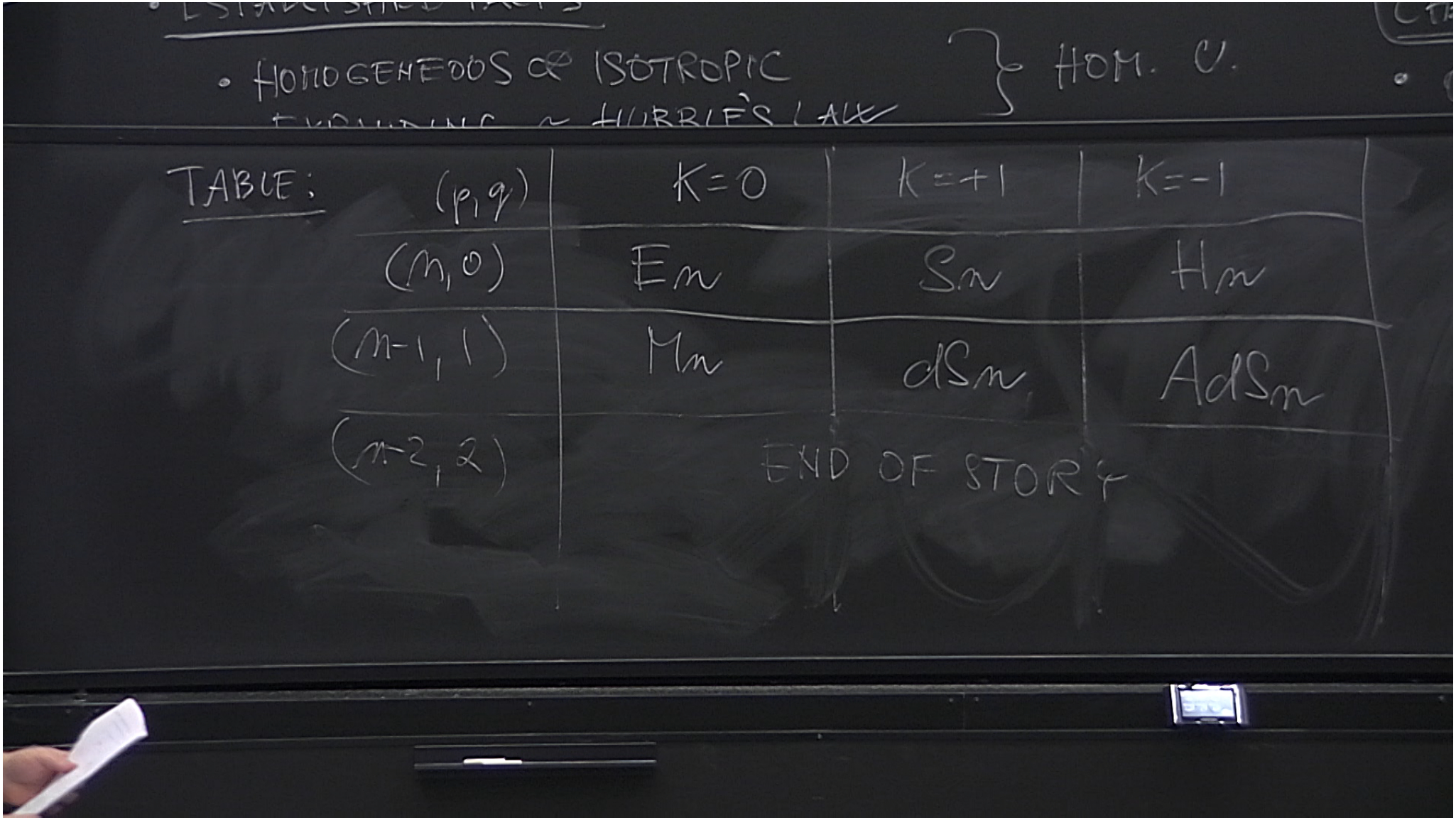
$$g_{ab}^{(p,q,K)} = \eta_{ab}^{(p,q)} + \frac{K\, x_a x_b}{\rho^2 - K x^2}$$

SOLUTION OF EI

$$R_{abcd} = \frac{K}{\rho^2}\left(g_{ac}\, g_{bd} - g_{ad}\, g_{bc}\right)$$




• HOMOGENEOUS & ISOTROPIC } HOM. C.
TABLE:
(p,q) | K=0 | K=+1 | K=-1
(n,0) | En | Sn | Hn
(n-1,1) | Mn | dSn | AdSn
(n-2,2)


• HOMOGENEOUS & ISOTROPIC
} HOM. U.
TABLE:
(p,q) | K=0 | K=+1 | K=-1
(n,0) | En | Sn | Hn
(n-1,1) | Mn | dSn | AdSn
(n-2,2) | END OF STORY

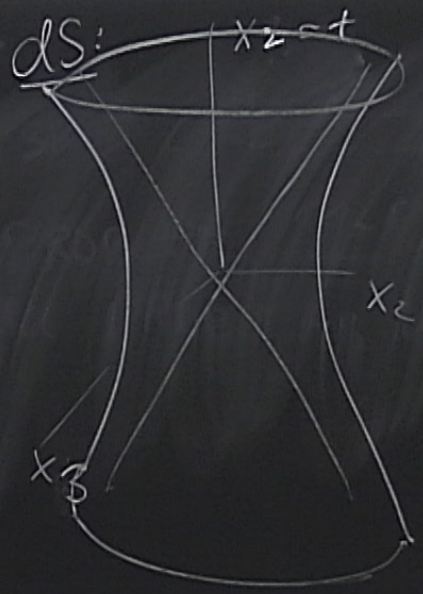
HOM. C.

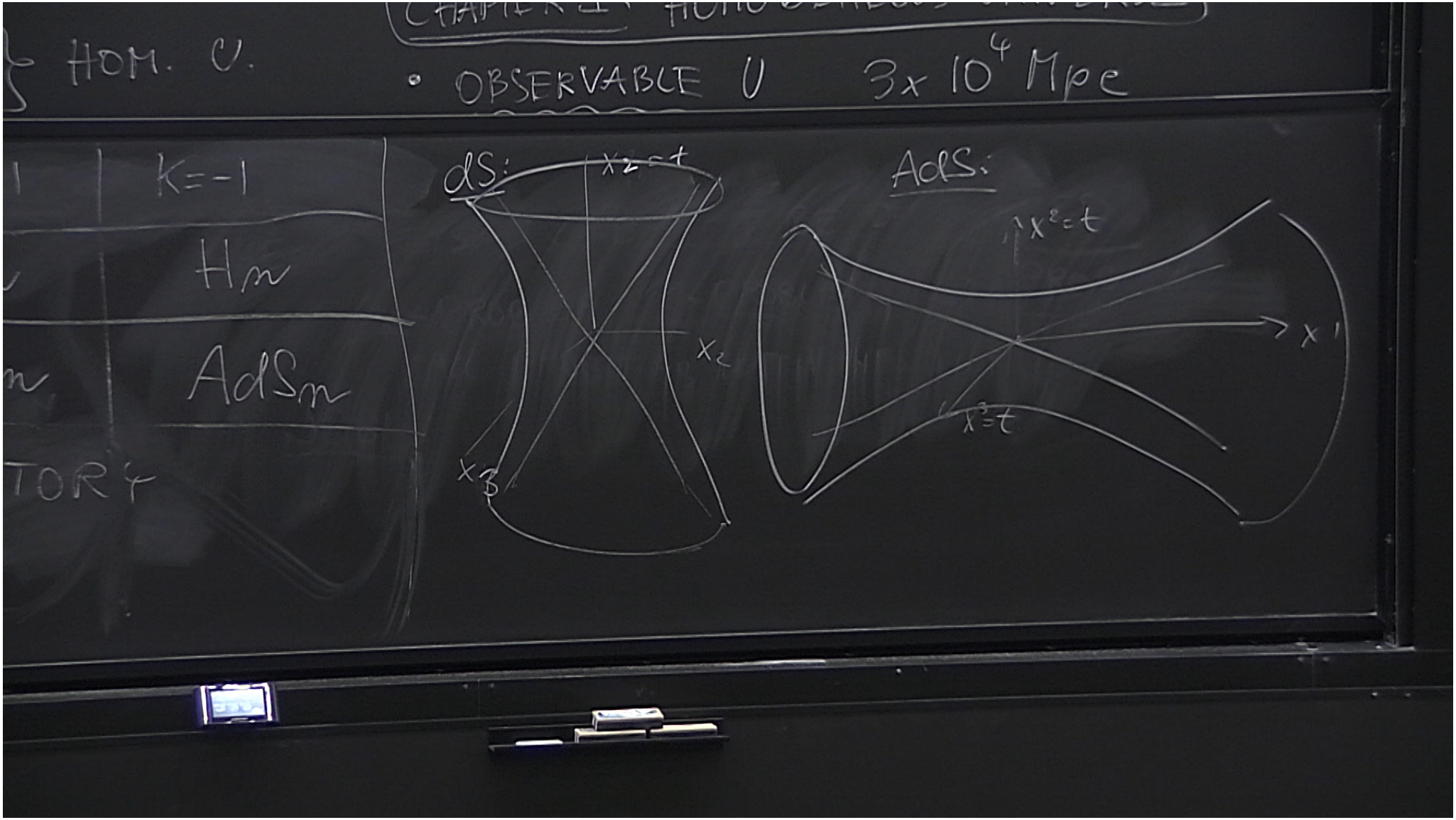
CHAPTER 1

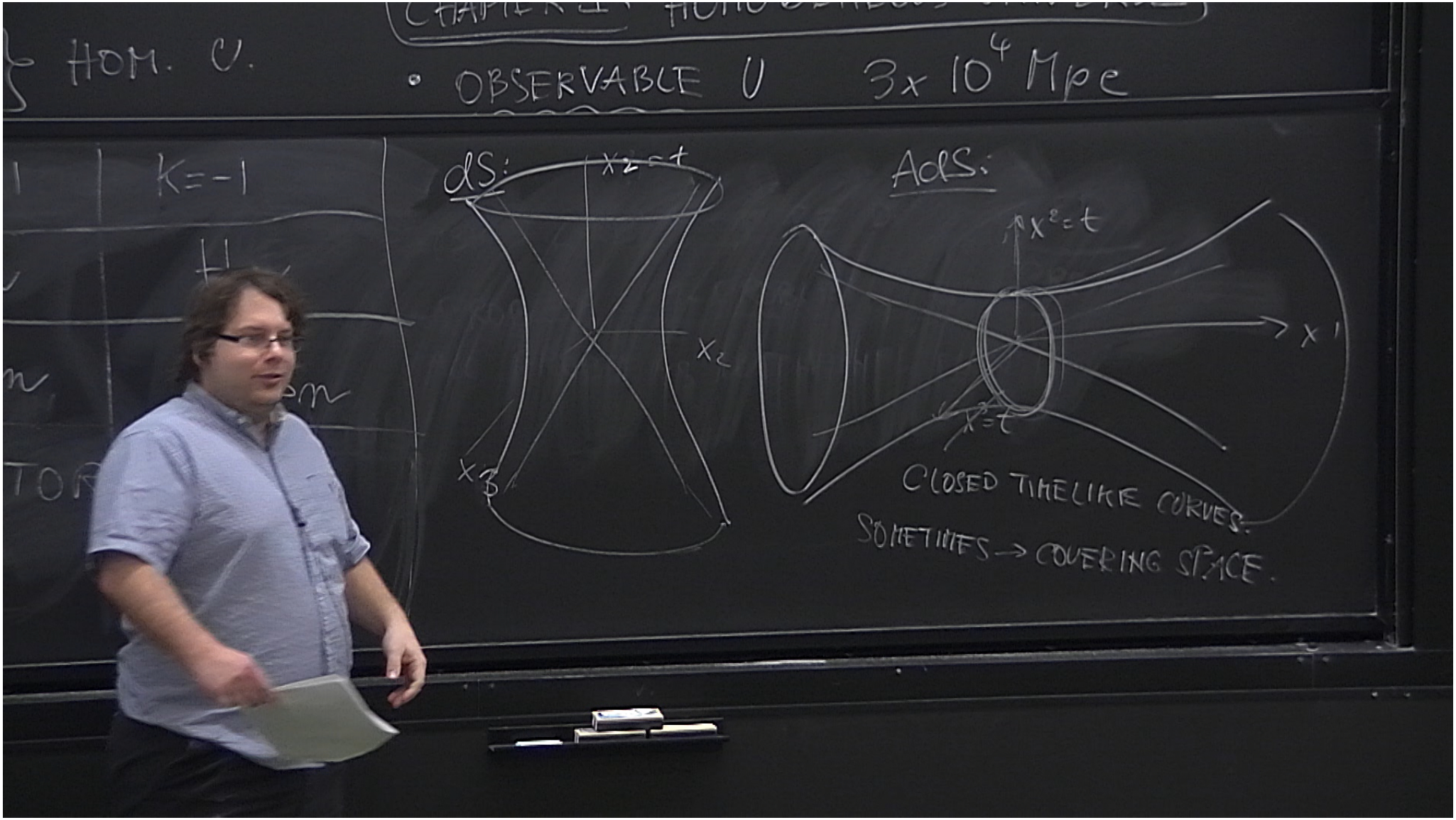
• OBSERVABLE U 3×10^4 Mpc

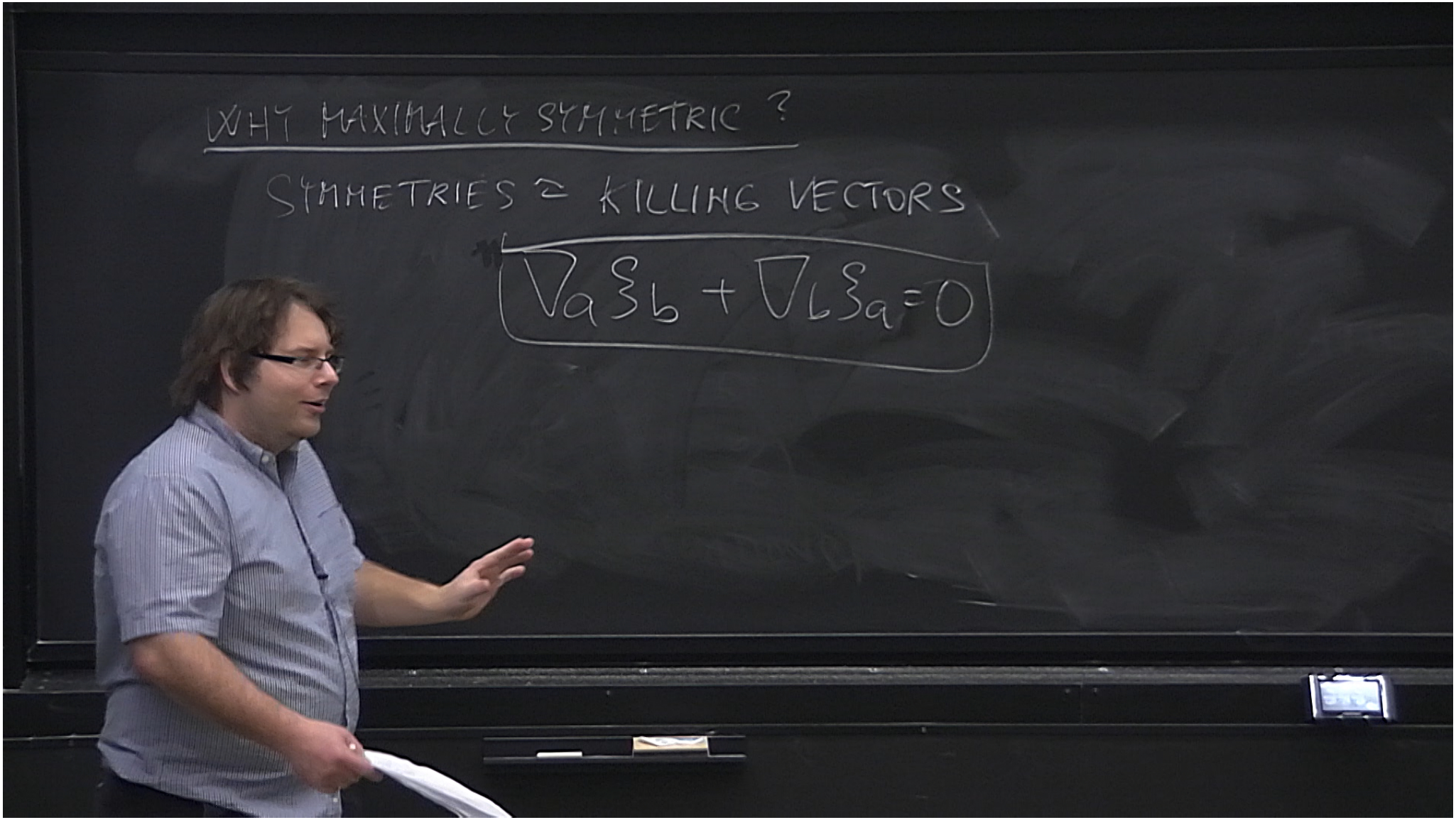
K=+1	K=-1
Sn	Hn
dSn	AdSn

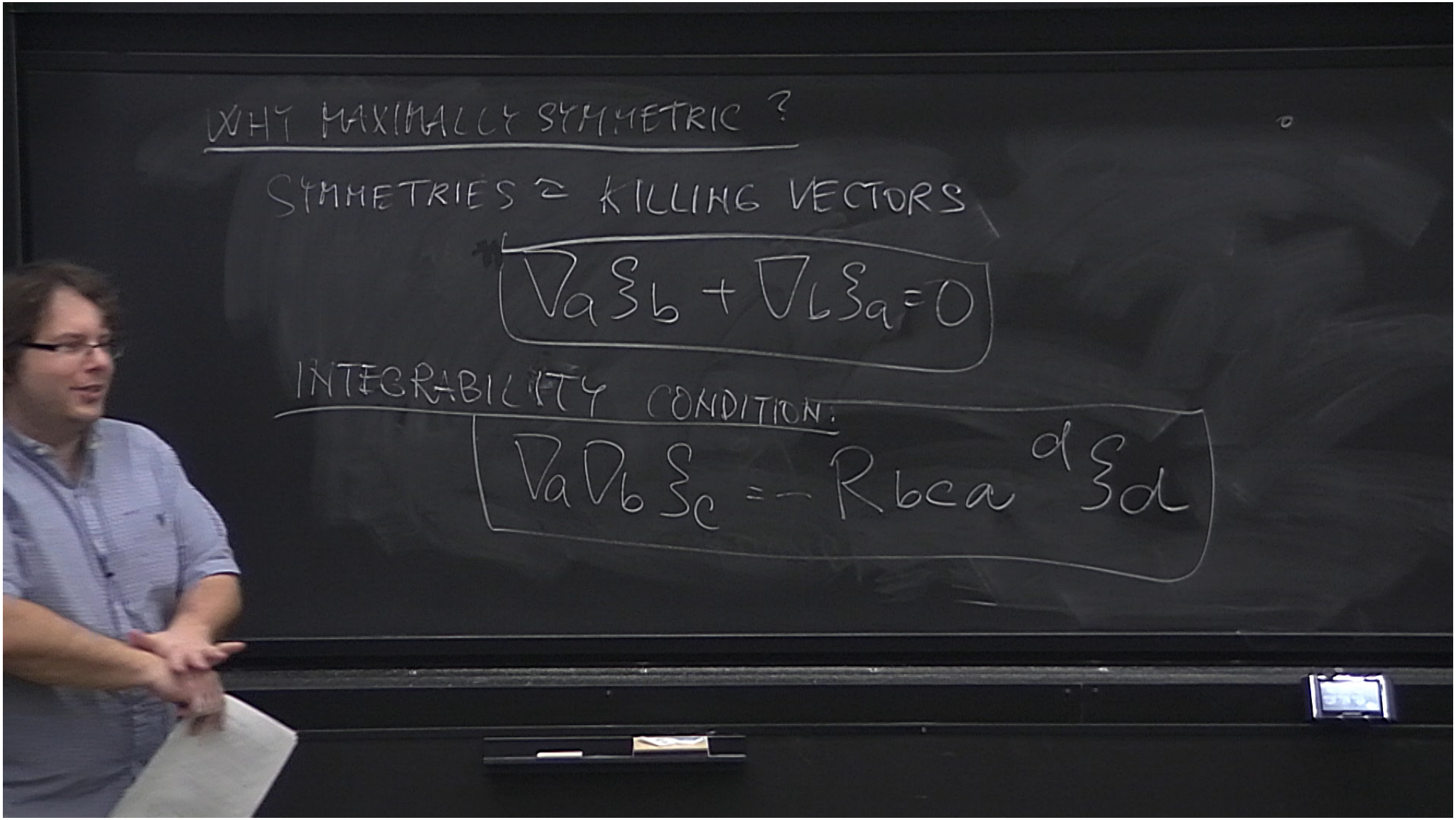
F STORY

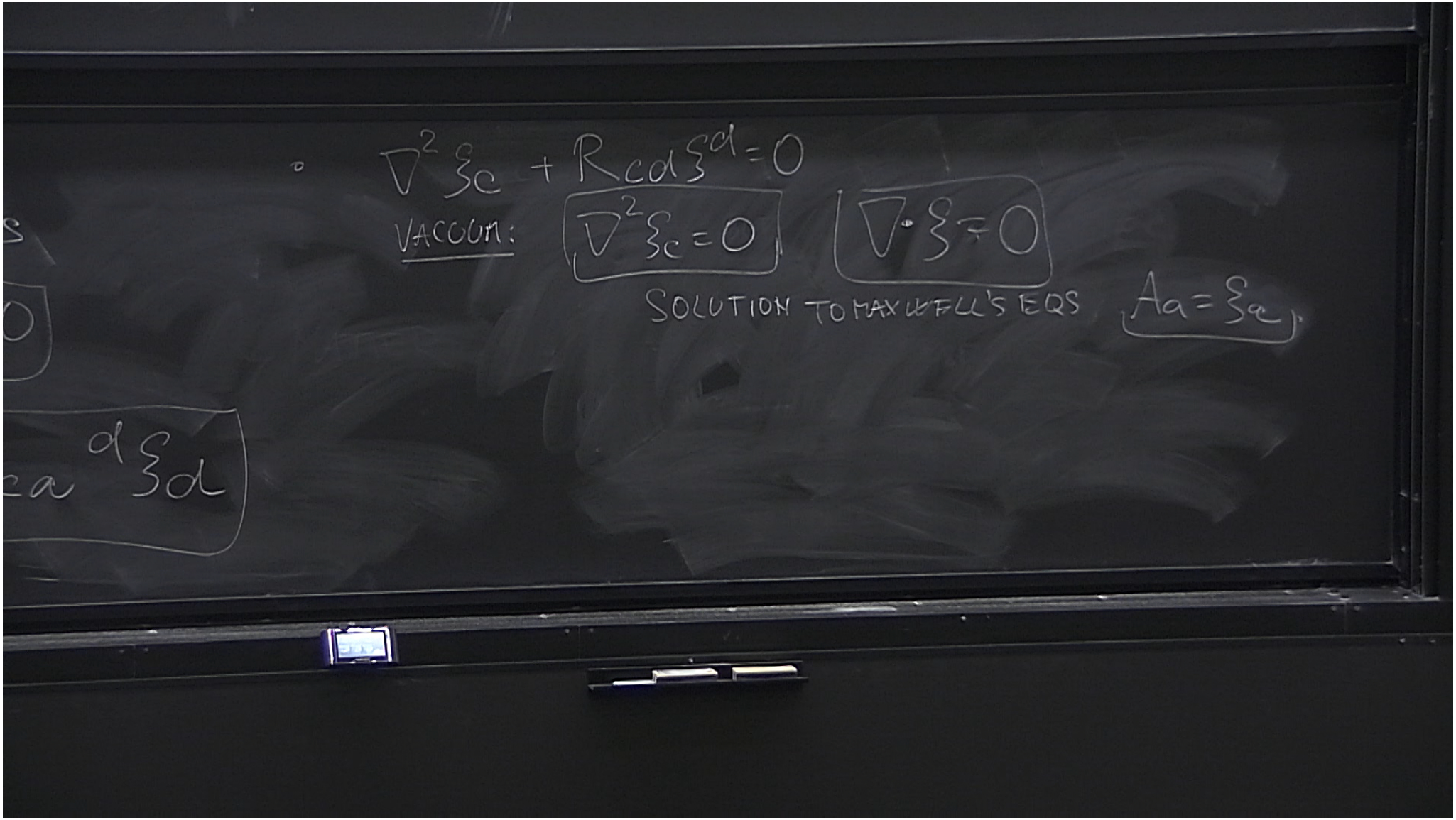


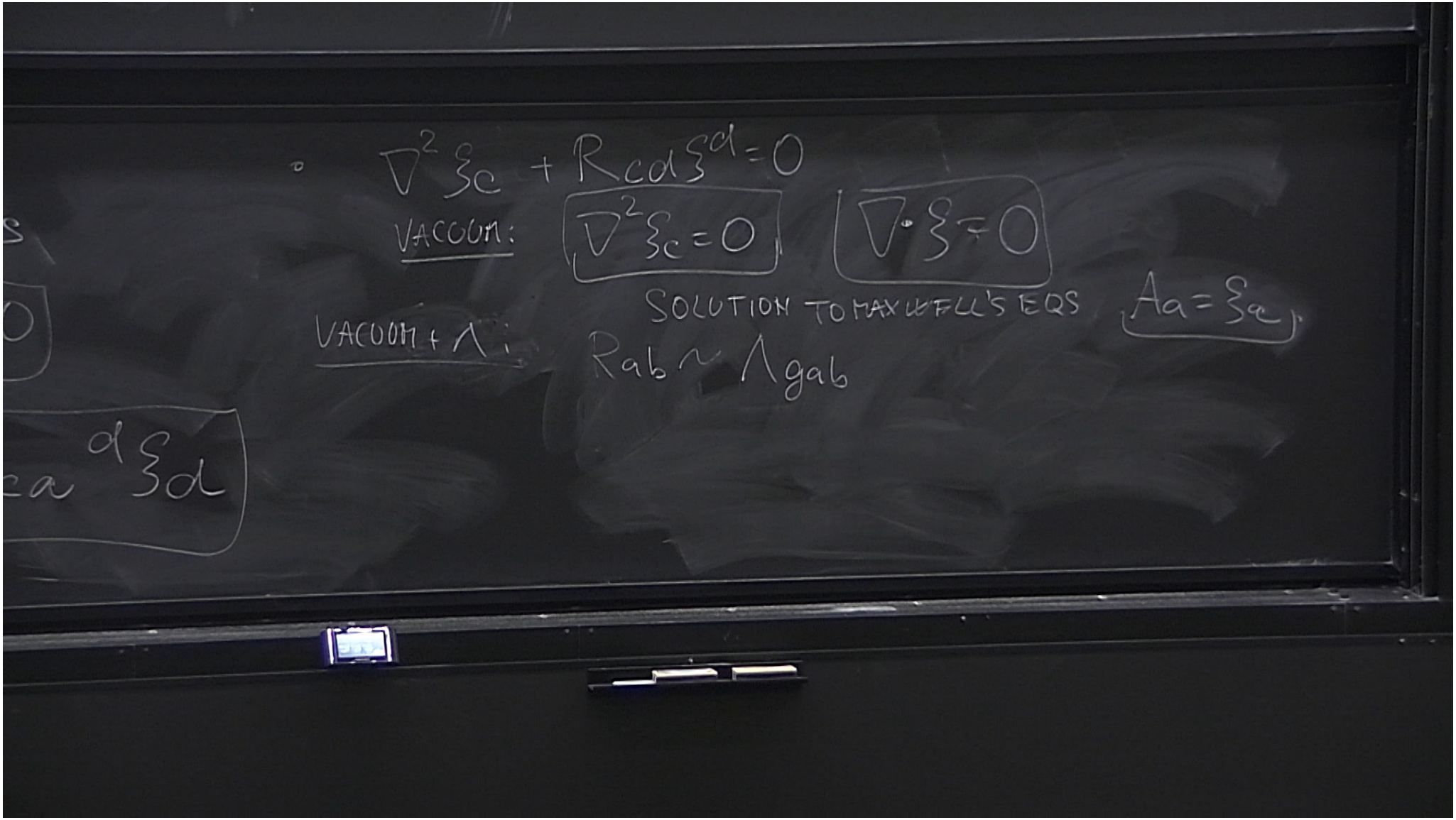

HOM. C.
• OBSERVABLE U
3×10^4 Mpc
K=-1
H_n
AdS_n
TORY
dS:
$x_2 = t$
x_2
x_3
AdS:
$x^2 = t$
x^1
$x^3 = t$

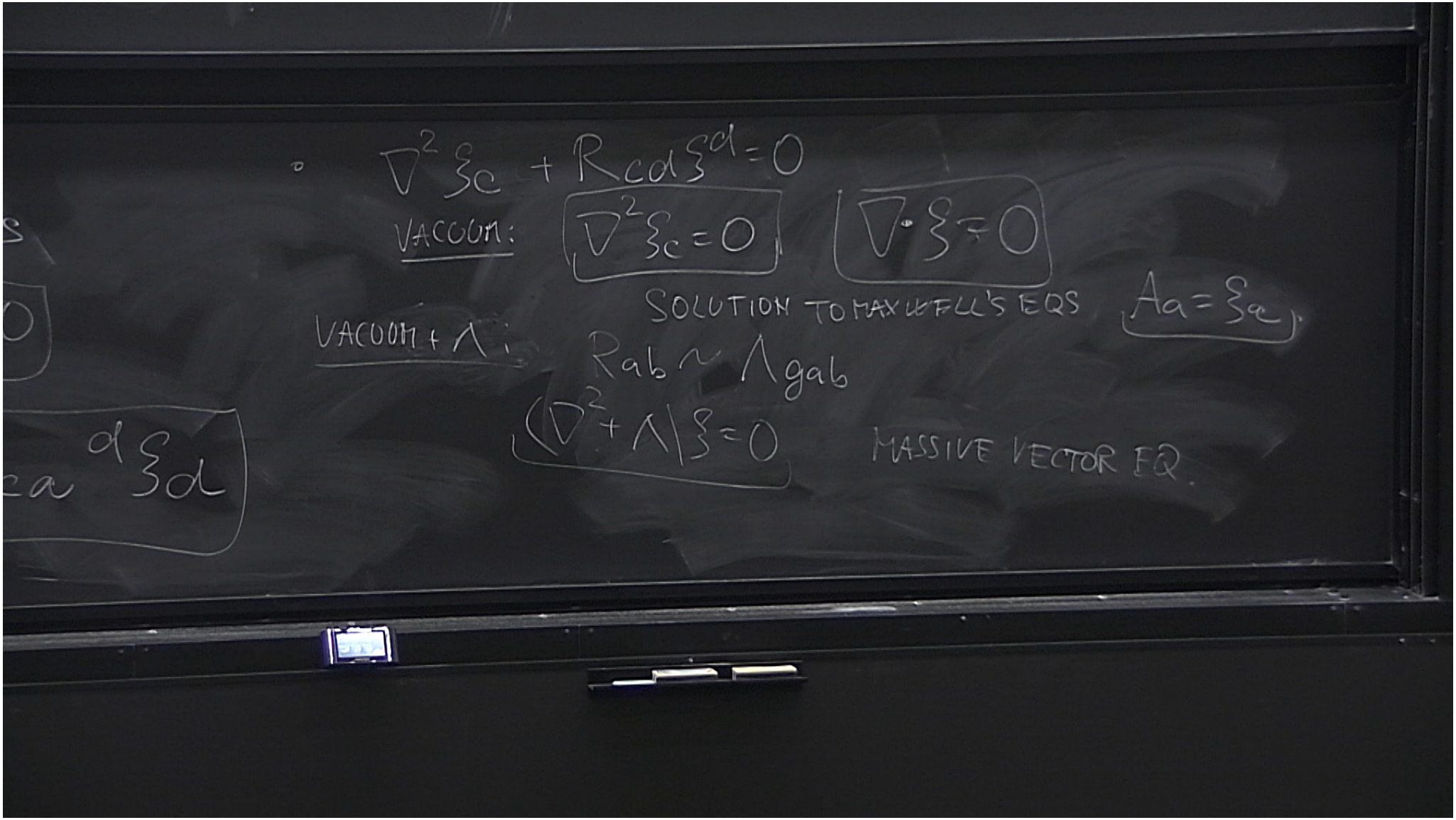

HOM. U.
• OBSERVABLE U
3x 10^4 Mpc
K=-1
dS:
AdS:
CLOSED TIMELIKE CURVES.
SOMETIMES → COVERING SPACE.

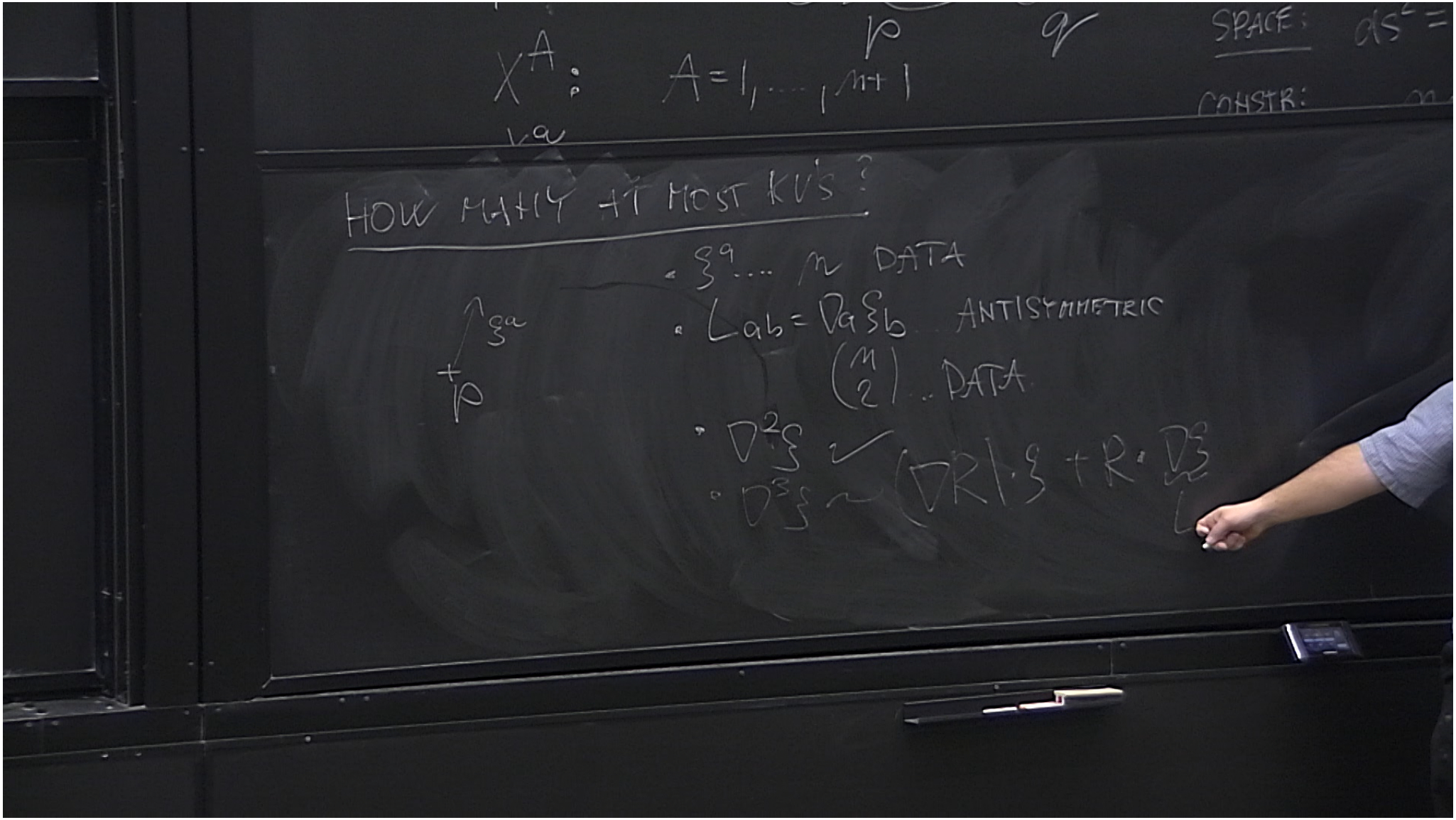

WHY MAXIMALLY SYMMETRIC ?
SYMMETRIES ≅ KILLING VECTORS
$\nabla_a \xi_b + \nabla_b \xi_a = 0$

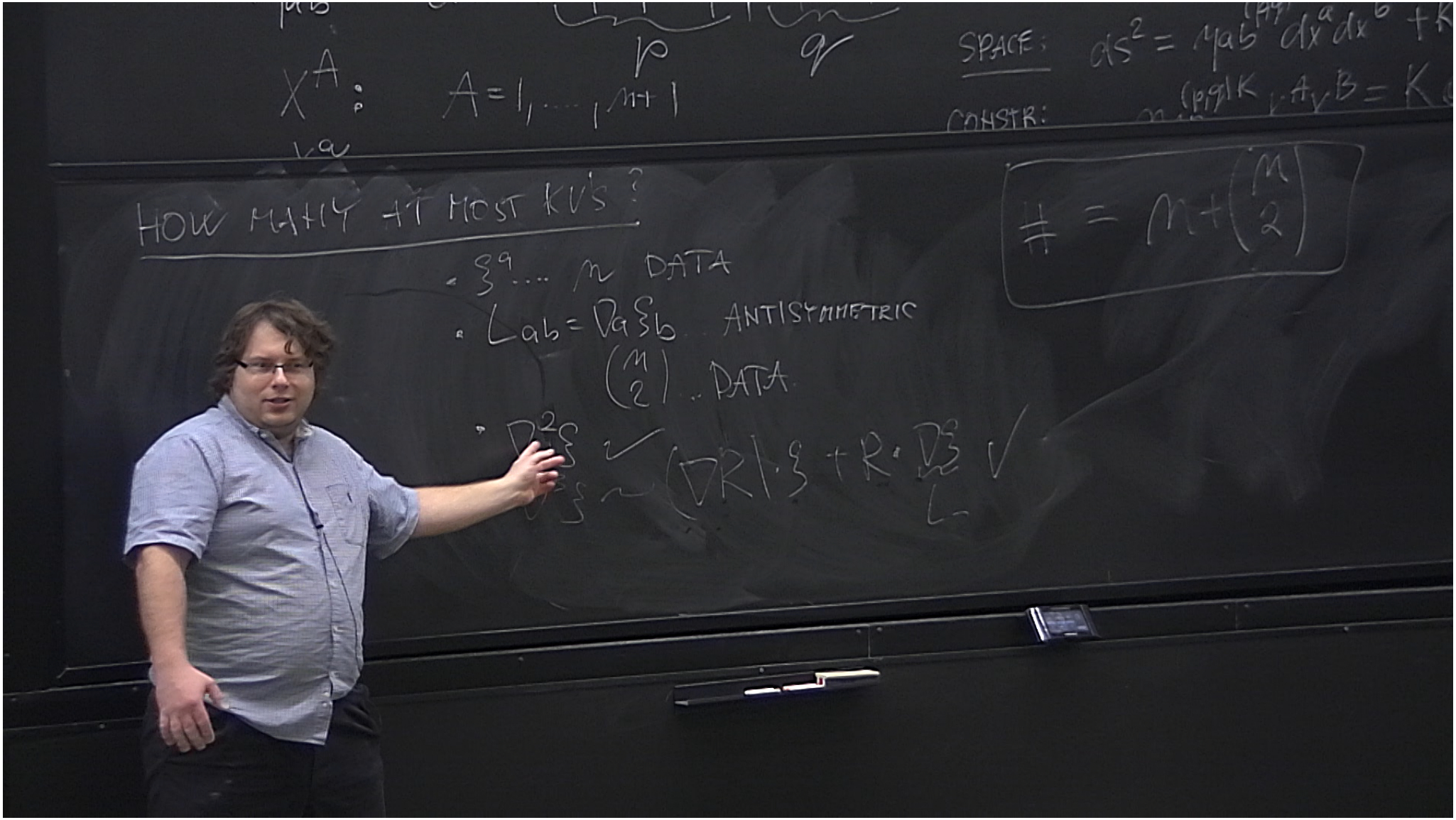

WHY MAXIMALLY SYMMETRIC ?
SYMMETRIES ≅ KILLING VECTORS
$\nabla_a \xi_b + \nabla_b \xi_a = 0$
INTEGRABILITY CONDITION:
$\nabla_a \nabla_b \xi_c = -R_{bca}{}^{d} \xi_d$


$\nabla^2 \xi_c + R_{cd} \xi^d = 0$
VACCUM: $\nabla^2 \xi_c = 0$
$\nabla \cdot \xi = 0$
SOLUTION TO MAXWELL'S EQS $A_a = \xi_a$


$\nabla^2 \xi_c + R_{cd} \xi^d = 0$
VACUUM: $\nabla^2 \xi_c = 0$
$\nabla \cdot \xi = 0$
SOLUTION TO MAXWELL'S EQS $A_a = \xi_a$
VACUUM + Λ: $R_{ab} \sim \Lambda g_{ab}$


$\nabla^2 \xi_c + R_{cd}\xi^d = 0$
VACUUM: $\nabla^2 \xi_c = 0$
$\nabla \cdot \xi = 0$
SOLUTION TO MAXWELL'S EQS
$A_a = \xi_a$
VACUUM + Λ: $R_{ab} \sim \Lambda g_{ab}$
$(\nabla^2 + \Lambda)\xi = 0$
MASSIVE VECTOR EQ.


SPACE:
CONSTR:
HOW MANY AT MOST KV's ?
DATA
ANTISYMMETRIC
DATA


SPACE:
CONSTR:
HOW MANY AT MOST KV's ?
- ξ^a ... n DATA
- L_ab = D_a ξ_b ANTISYMMETRIC
(n 2) .. DATA
n + (n 2)