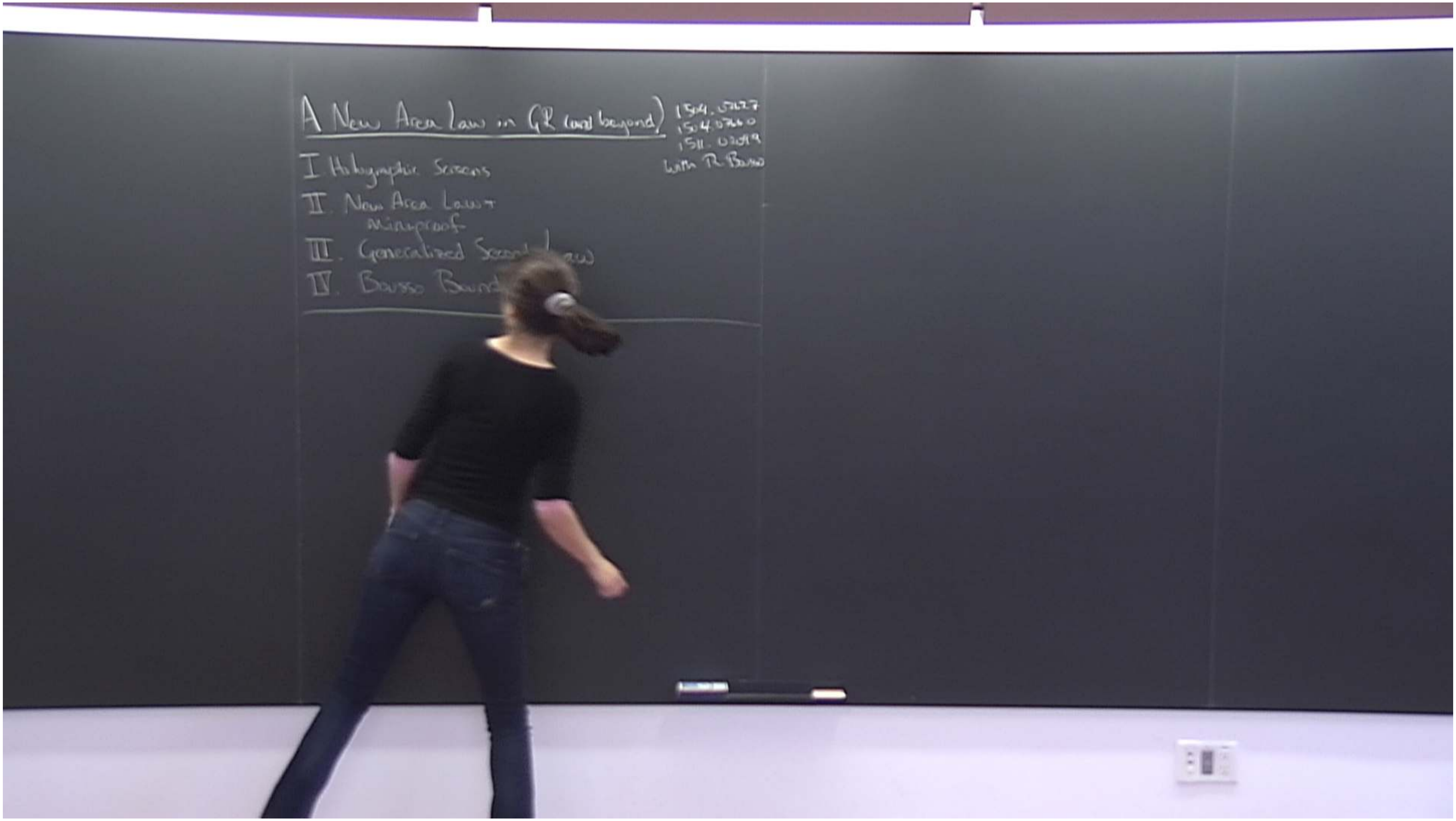
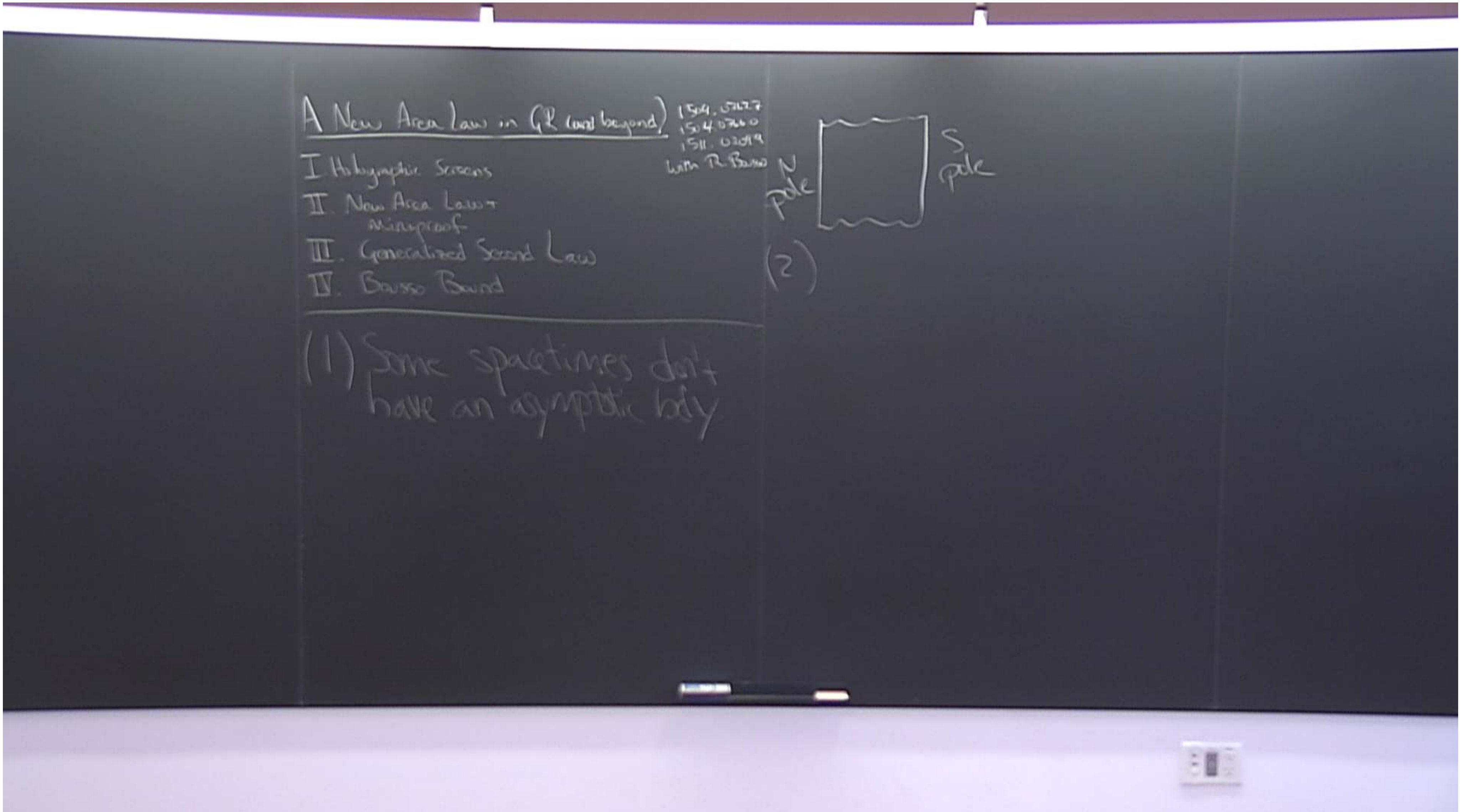
Title: A New Area Law in General Relativity (and beyond)

Date: Dec 14, 2015 02:00 PM

URL: http://pirsa.org/15120038

Abstract: <p>I will present a new area law in General Relativity. This new area law holds on local analogues of event horizons that have an independent thermodynamic significance due to the Bousso bound. I will also discuss a quantum generalization of this more local notion of thermodynamics.</p>


A New Area Law in GR (and beyond)
with R. Bousso
I. Holographic Screens
II. New Area Law + miniproof
III. Generalized Second
IV. Bousso Bound


A New Area Law in GR (and beyond)
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I Holographic Screens
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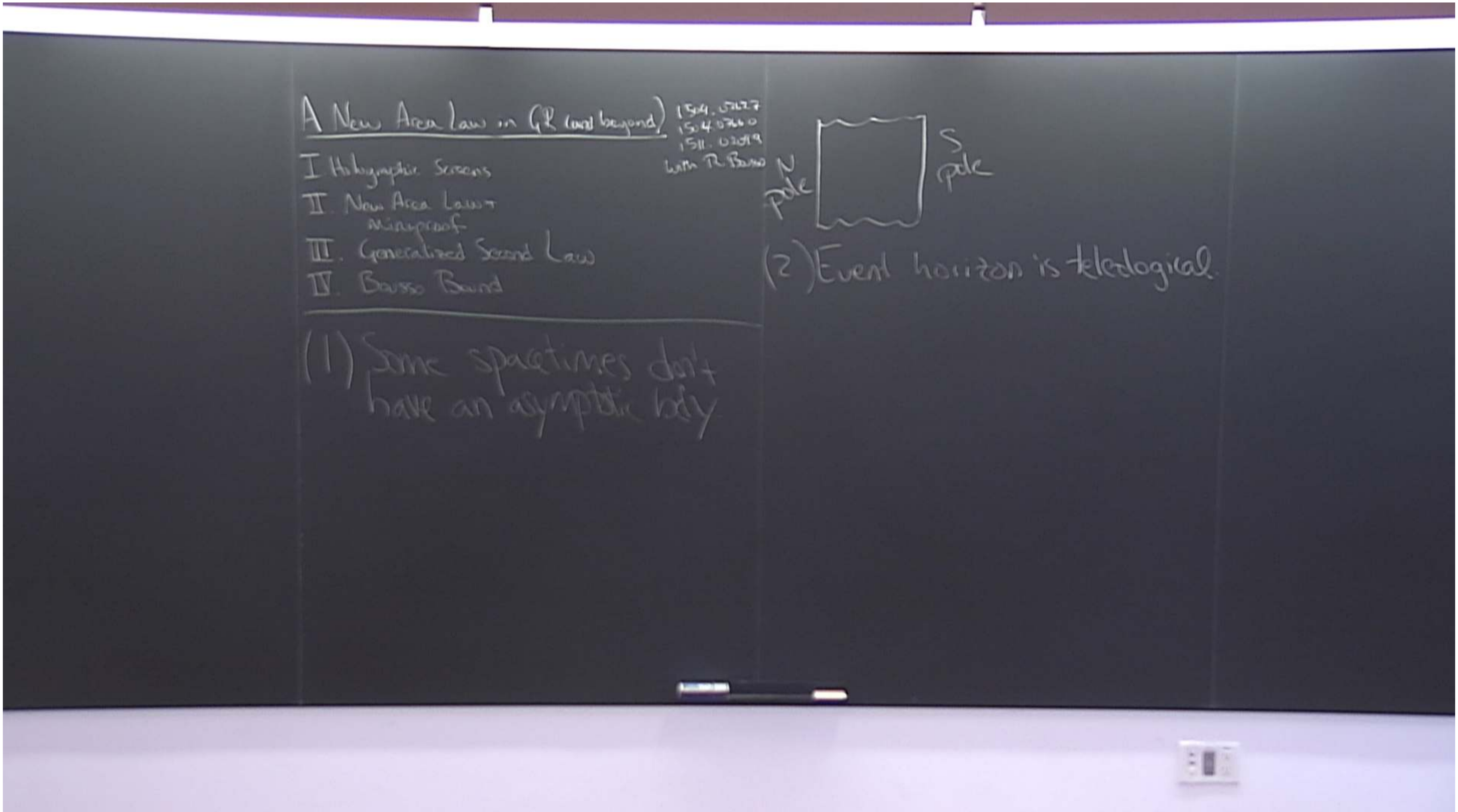
III. Generalized Second Law
IV. Bousso Bound
(1) Some spacetimes don't have an asymptotic bdy
(2)
N pole
S pole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(1) Some spacetimes don't have an asymptotic bdy
N pole
S pole
(2) Event horizon is teleological

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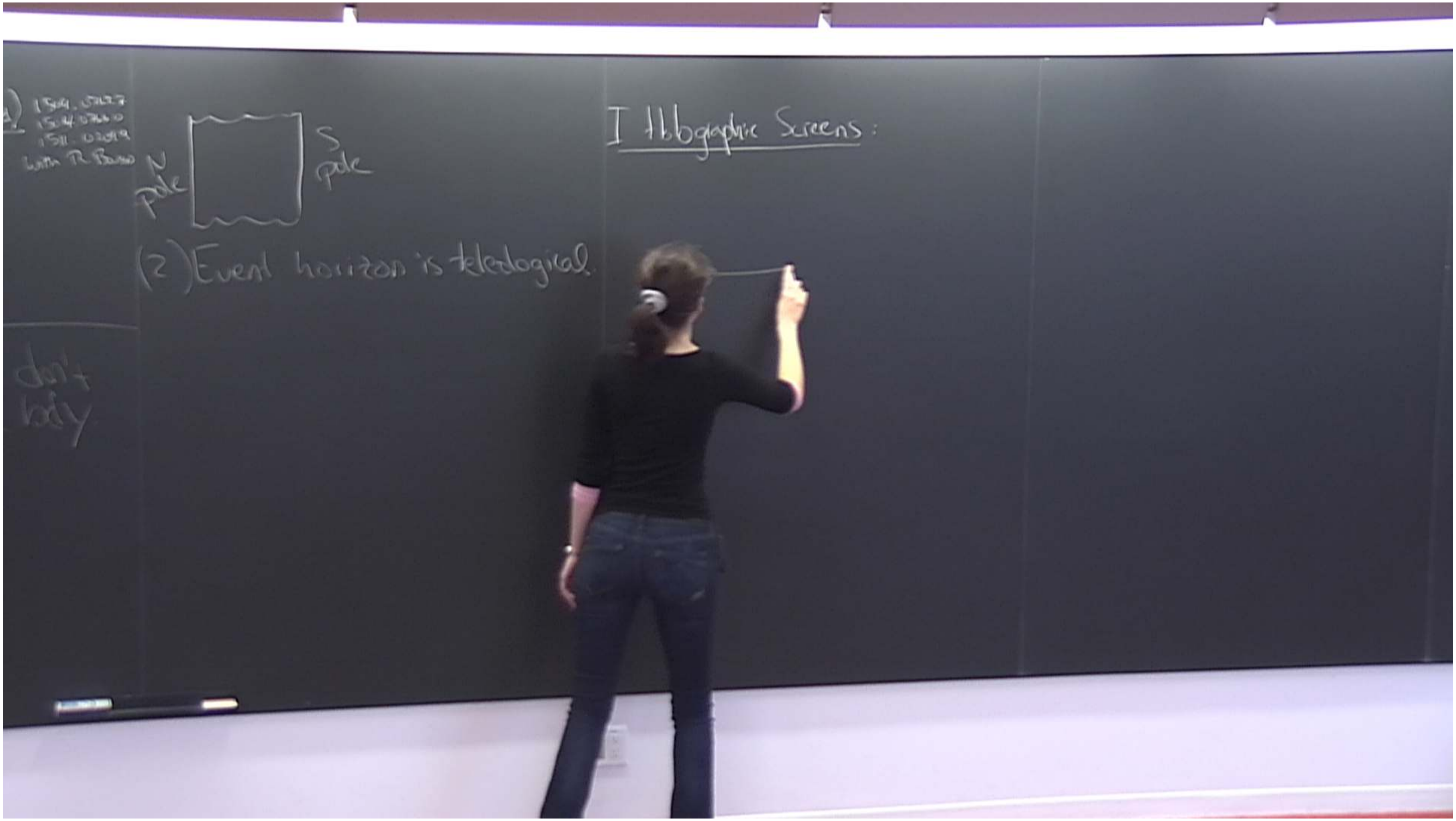
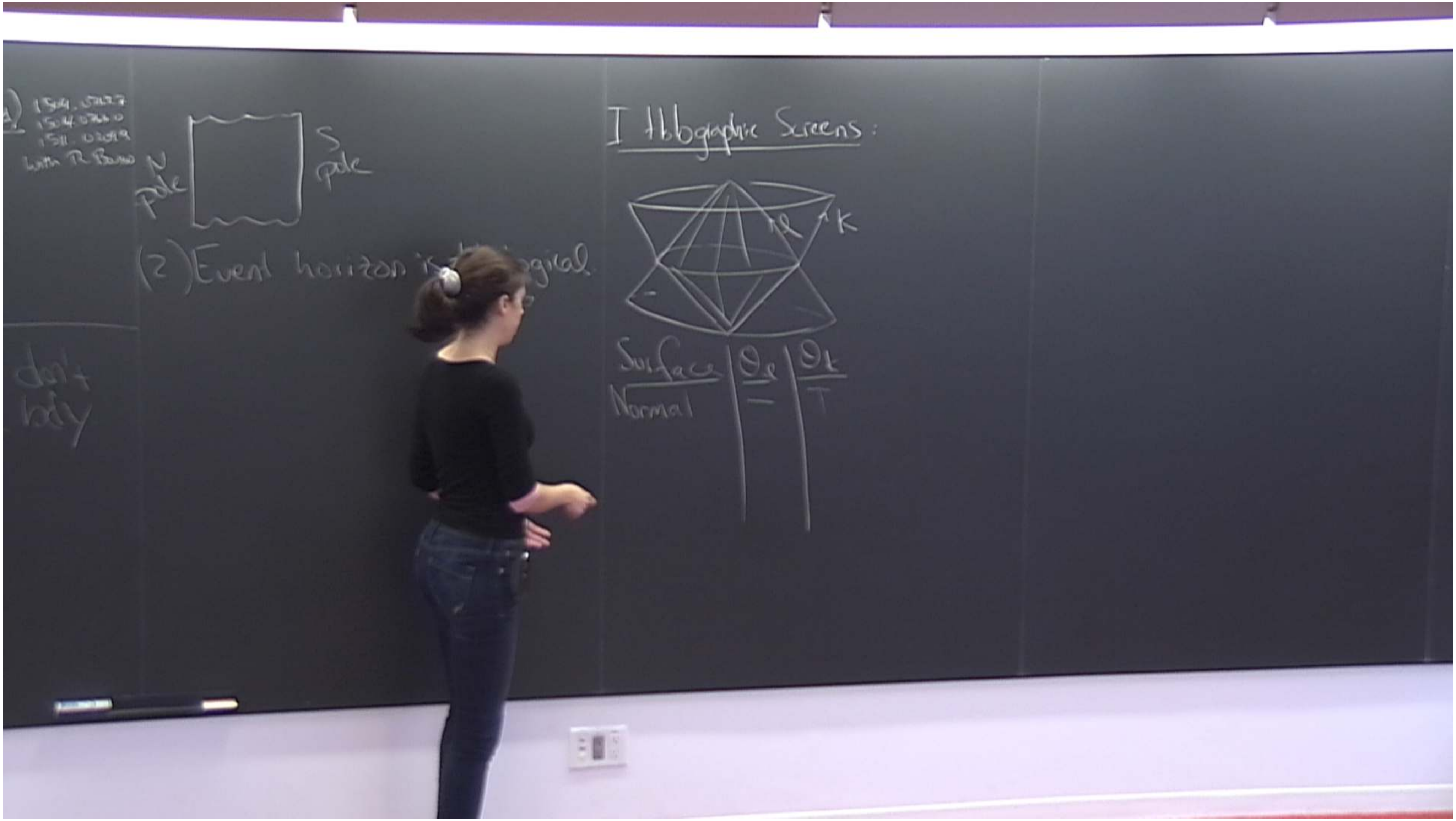
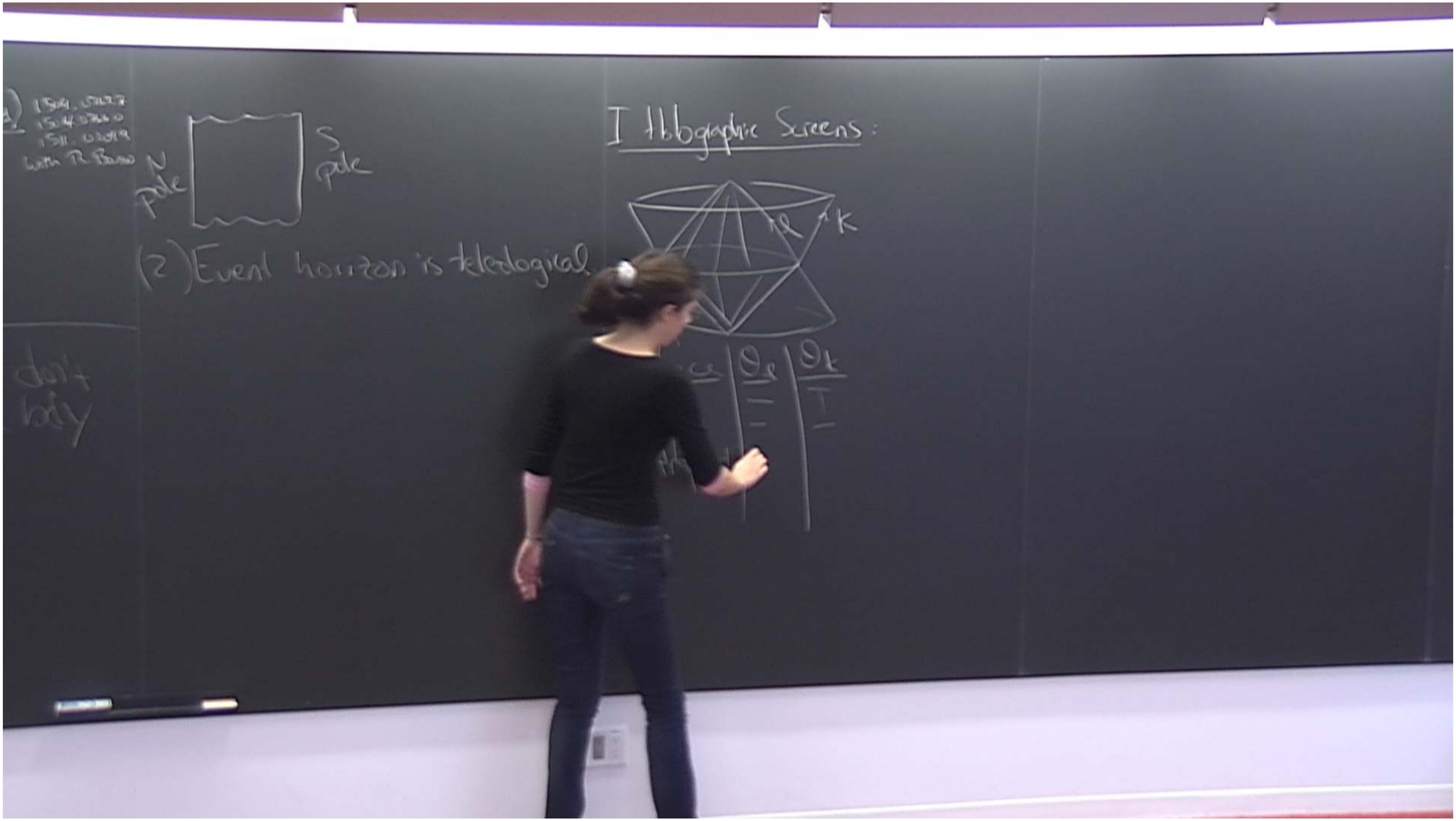
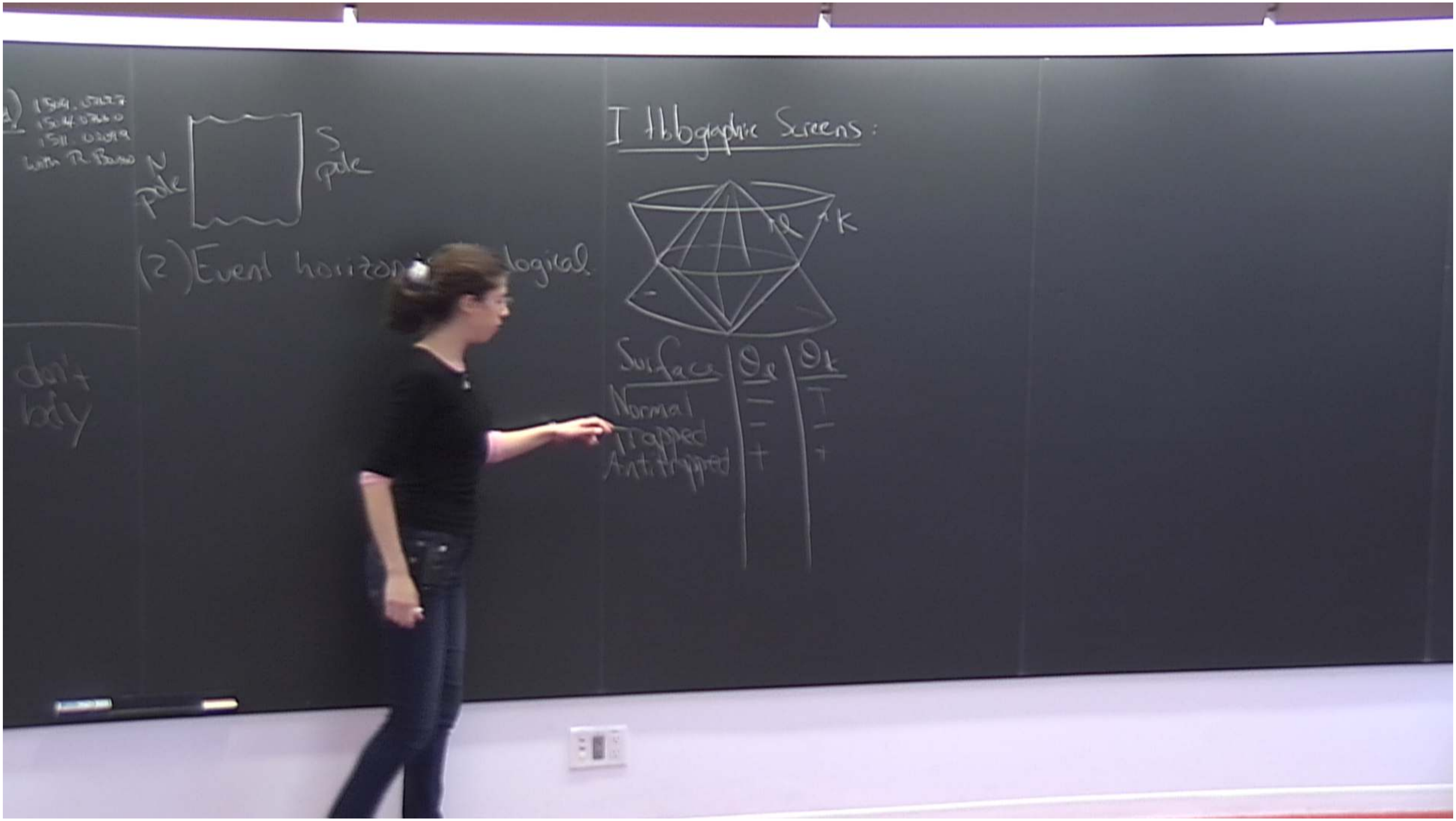
(1) Some spacetimes don't have an asymptotic bdy.
N pole
S pole

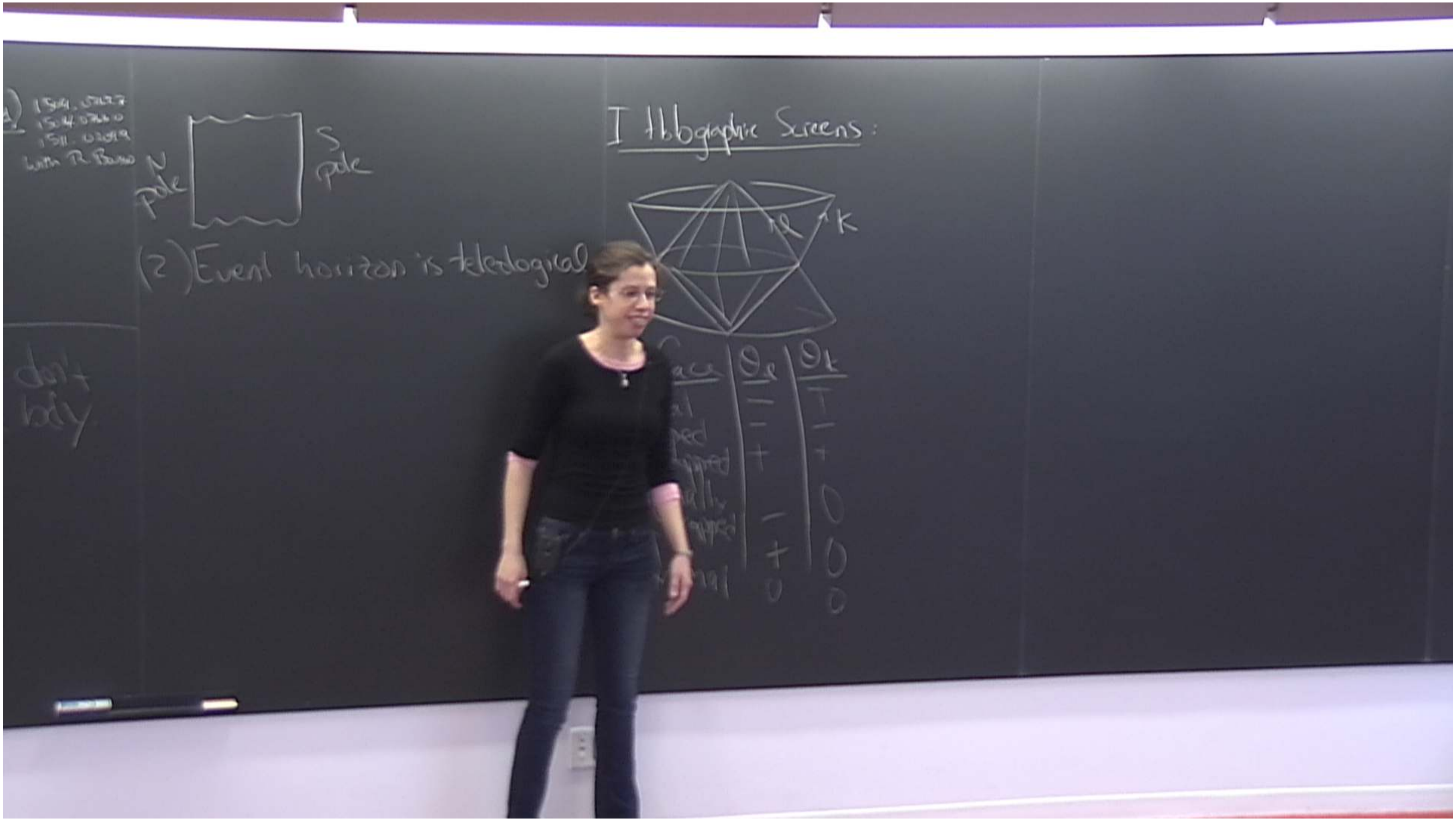

1504.05227
1504.07660
1511.02049
with R. Bousso
N pole
S pole
(2) Event horizon is teleological
I Holographic Screens:

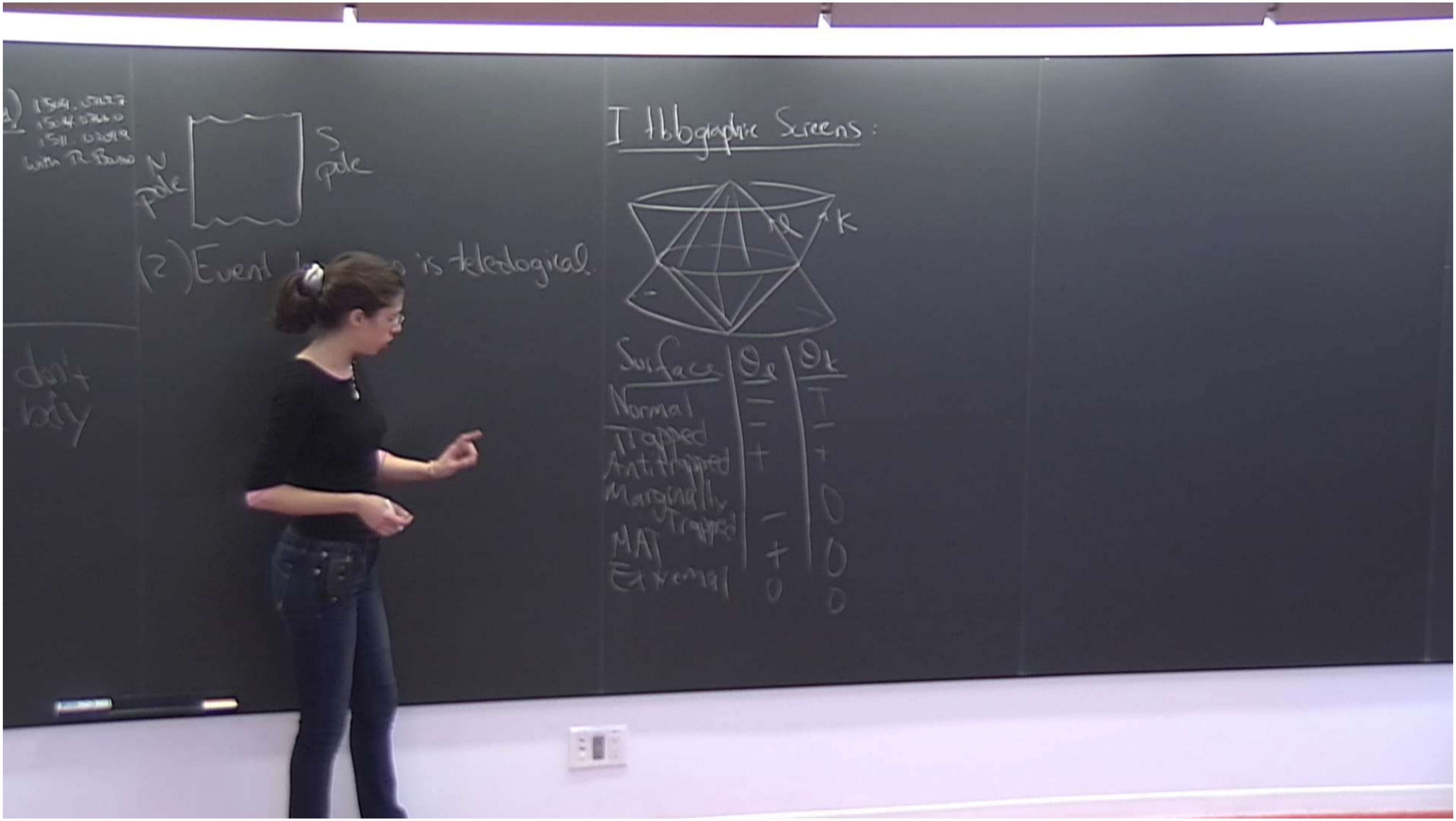
1509.…
1511.…
with R. Bousso
N pole
S pole
(2) Event horizon is teleological
I Holographic Screens:

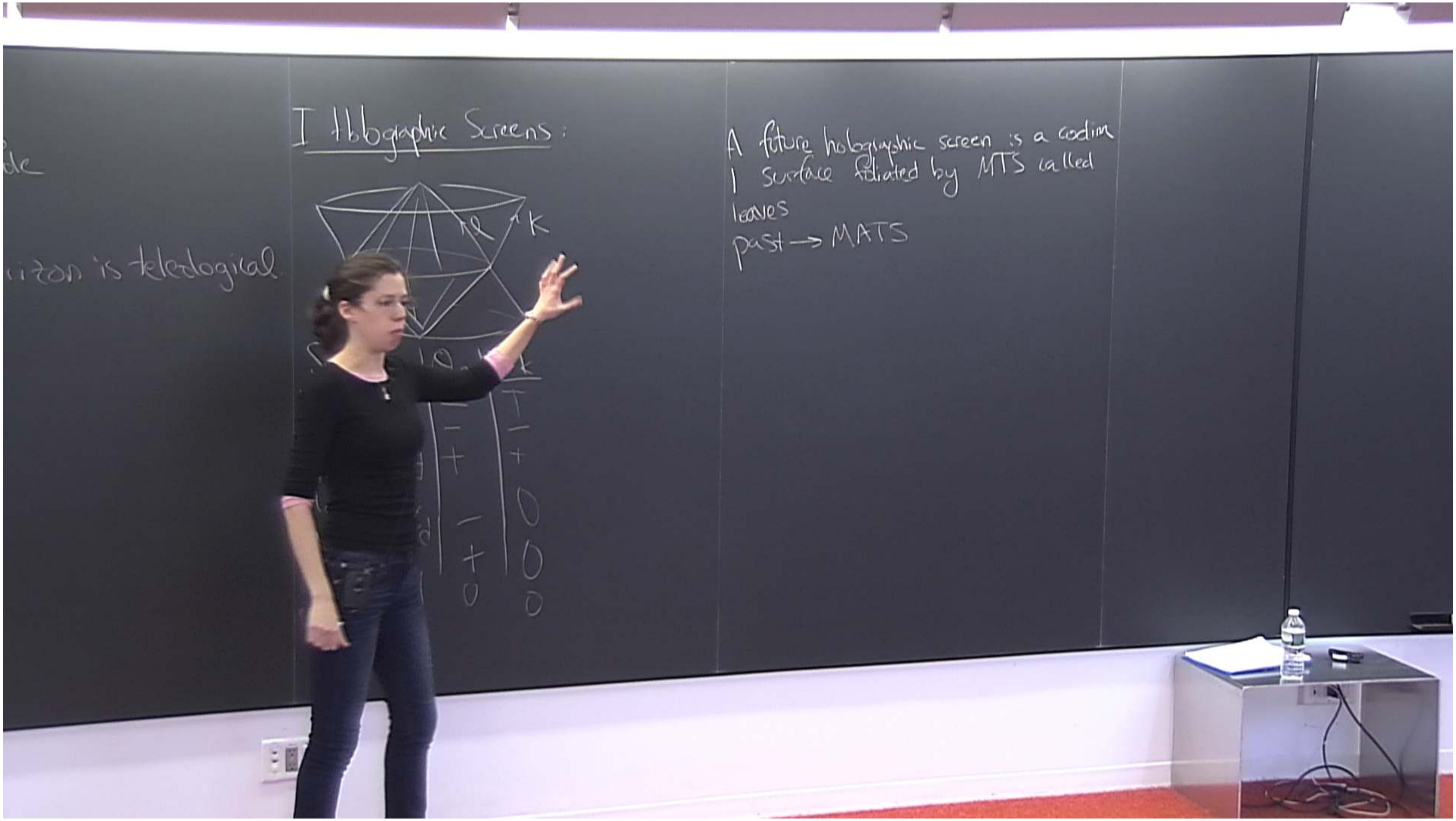

N pole
S pole
(2) Event horizon is
I Holographic Screens:
k
Surface Normal

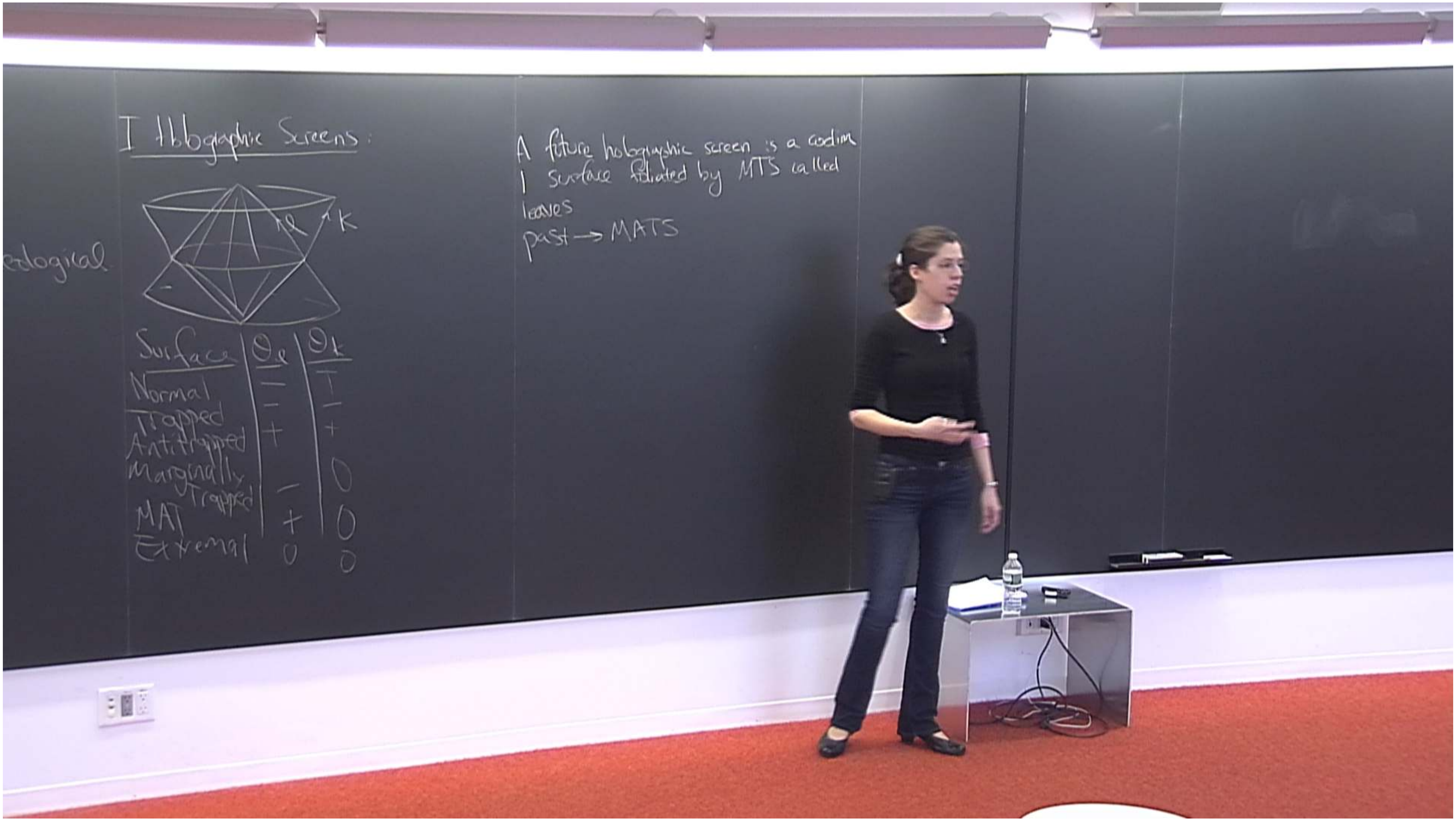

I Holographic Screens:
N pole
S pole
(2) Event horizon is teleological
k

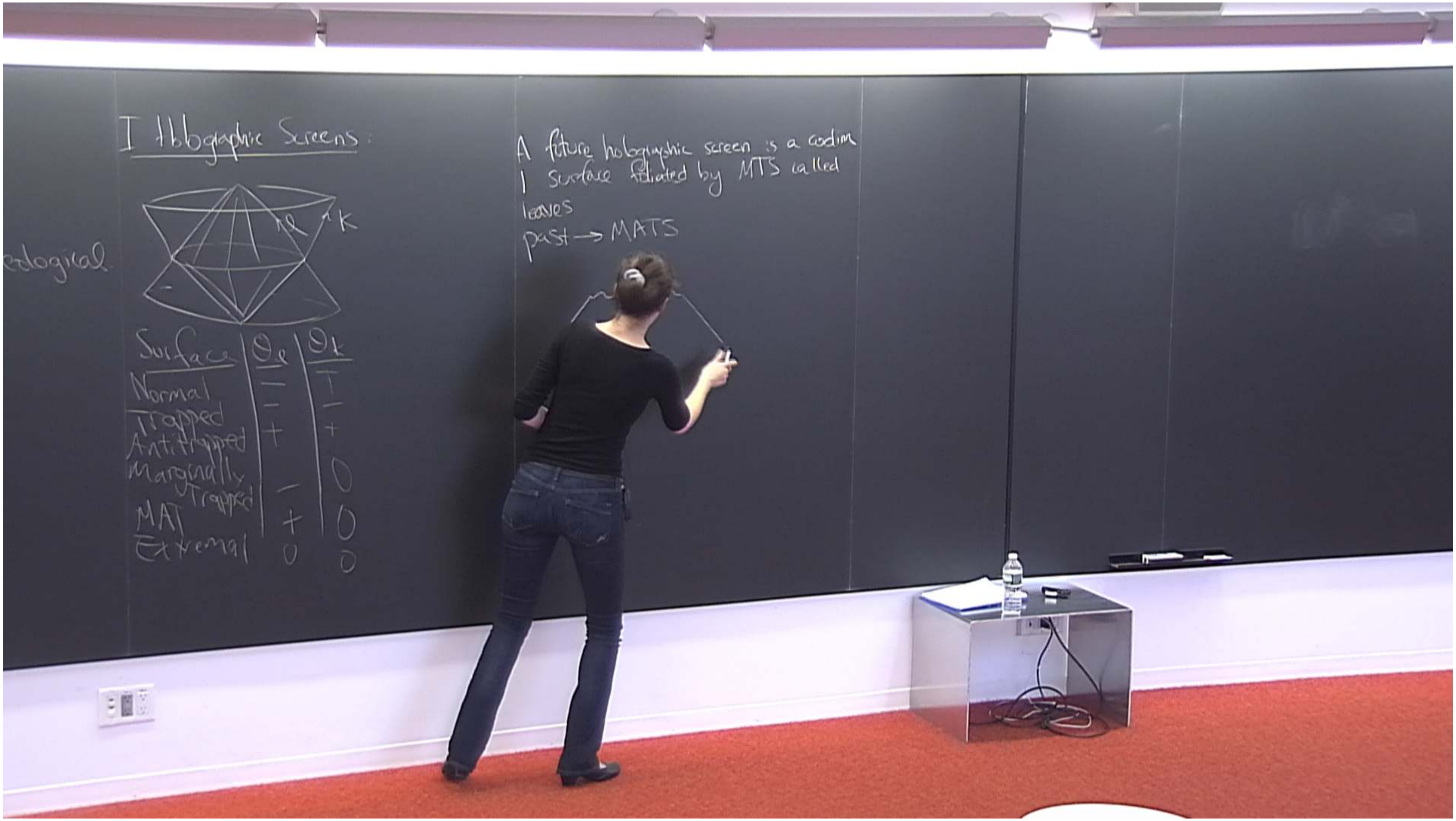

I Holographic Screens:
Surface | θ_ℓ | θ_k
Normal | − | +
Trapped | − | −
Antitrapped | + | +
(2) Event horizon
S pole
N pole

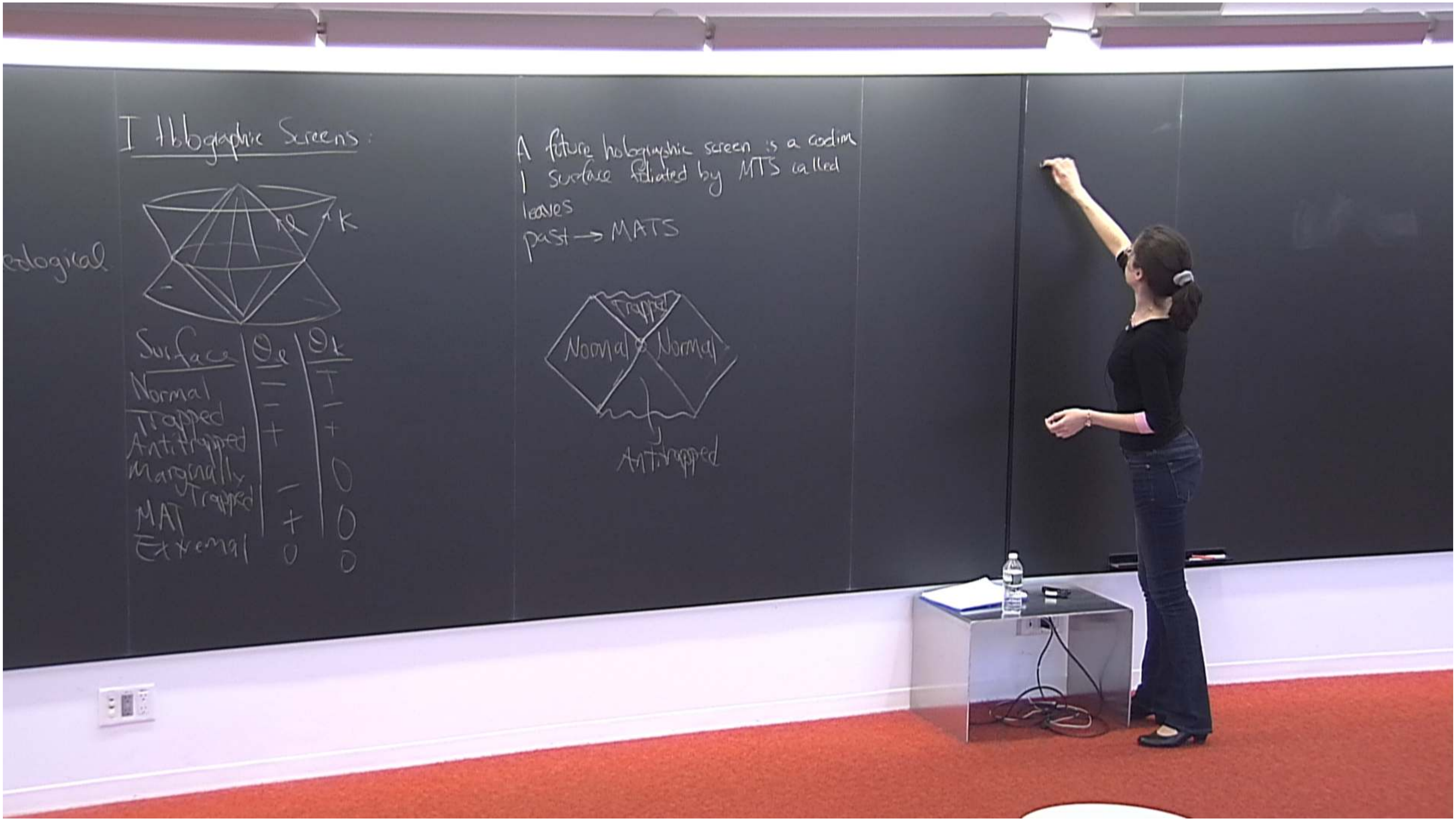

N pole
S pole
(2) Event horizon is teleological
Holographic Screens:
K

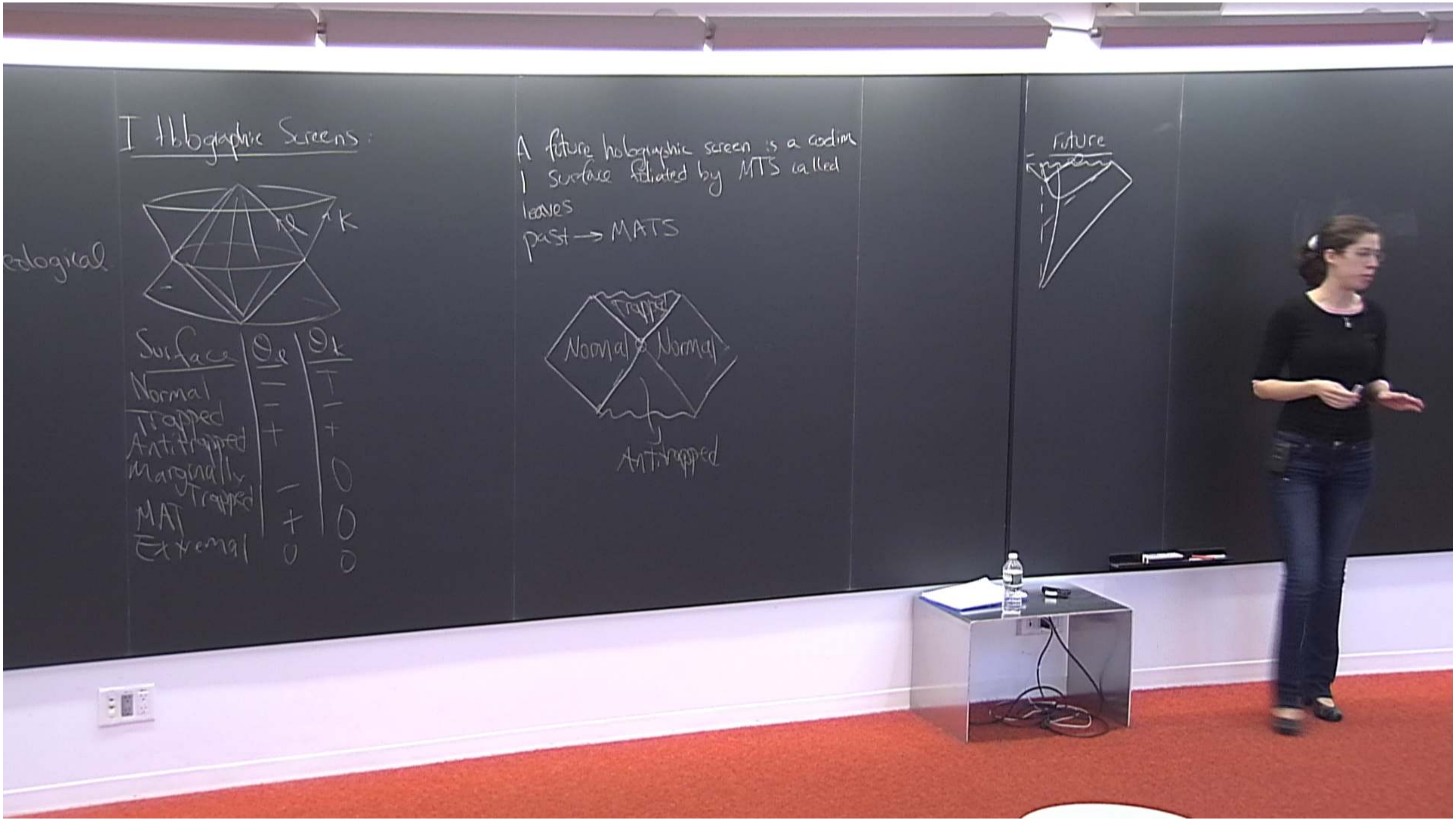

N pole
S pole
(2) Event
is teleological
I Holographic Screens:
K
Surface
Normal
Trapped
Antitrapped
Marginally Trapped
MAT
Extremal

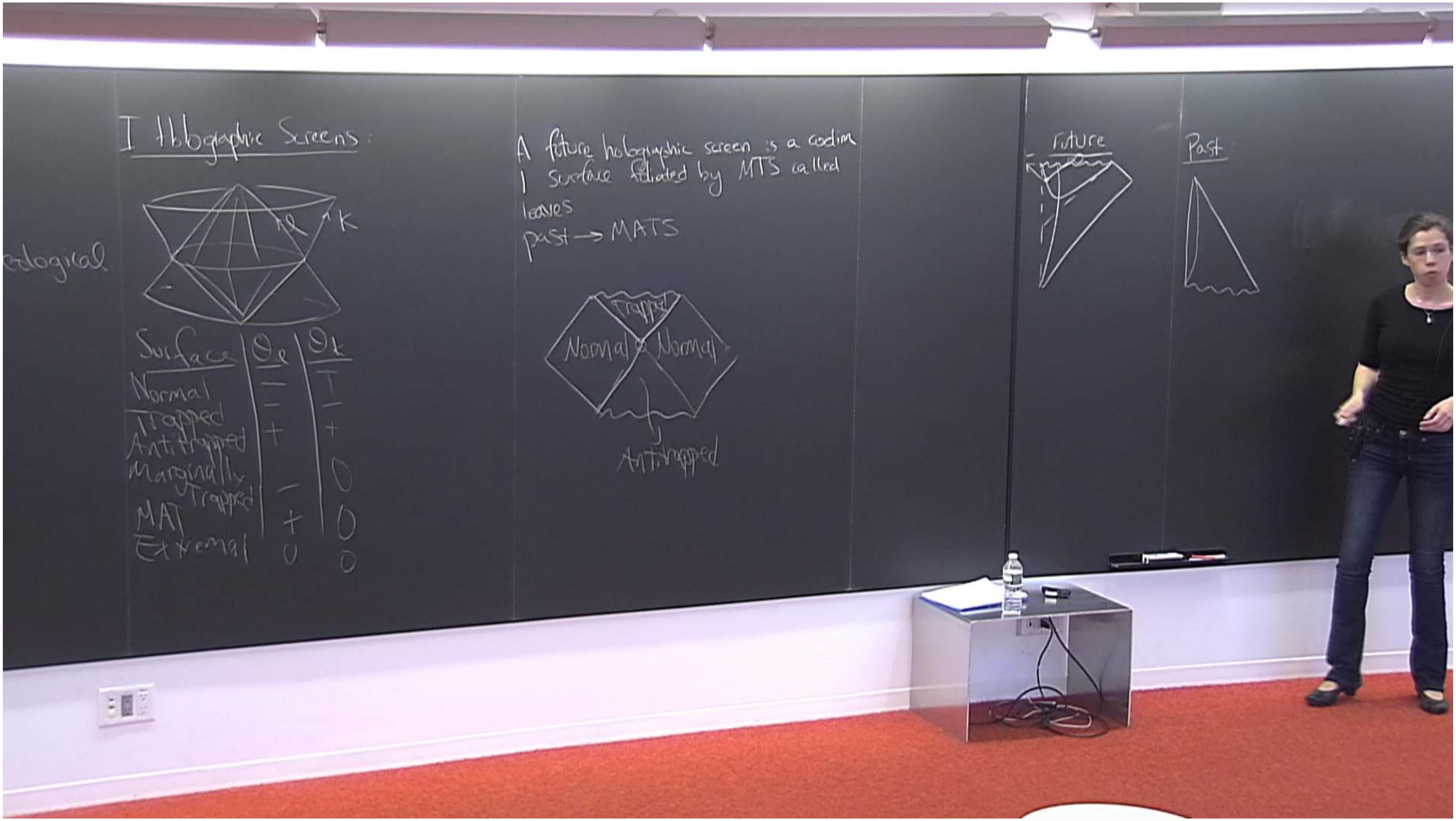

I Holographic Screens:
A future holographic screen is a codim
1 surface foliated by MTS called
leaves
past → MATS
rizon is teleological


I Holographic Screens:
l
k
Surface | θl | θk
Normal | − | +
Trapped | − | −
Antitrapped | + | +
Marginally Trapped | − | 0
MAT | + | 0
Extremal | 0 | 0
A future holographic screen is a codim 1 surface foliated by MTS called leaves
past → MATS

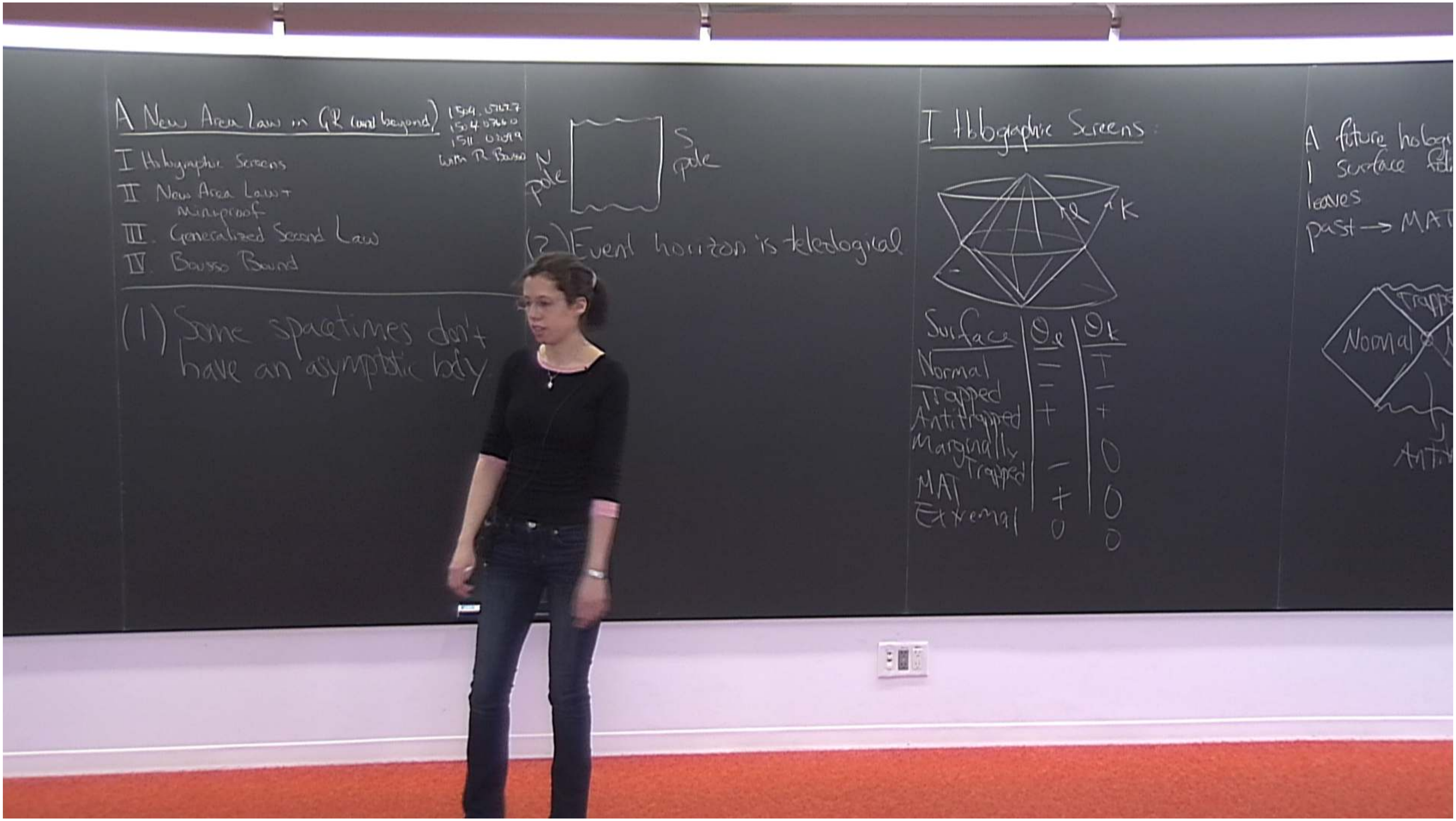

I Holographic Screens:
k
Surface | θ_ℓ | θ_k
Normal | − | +
Trapped | − | −
Antitrapped | + | +
Marginally Trapped | − | 0
MAT | + | 0
Extremal | 0 | 0
A future holographic screen is a codim 1 surface foliated by MTS called leaves
past → MATS

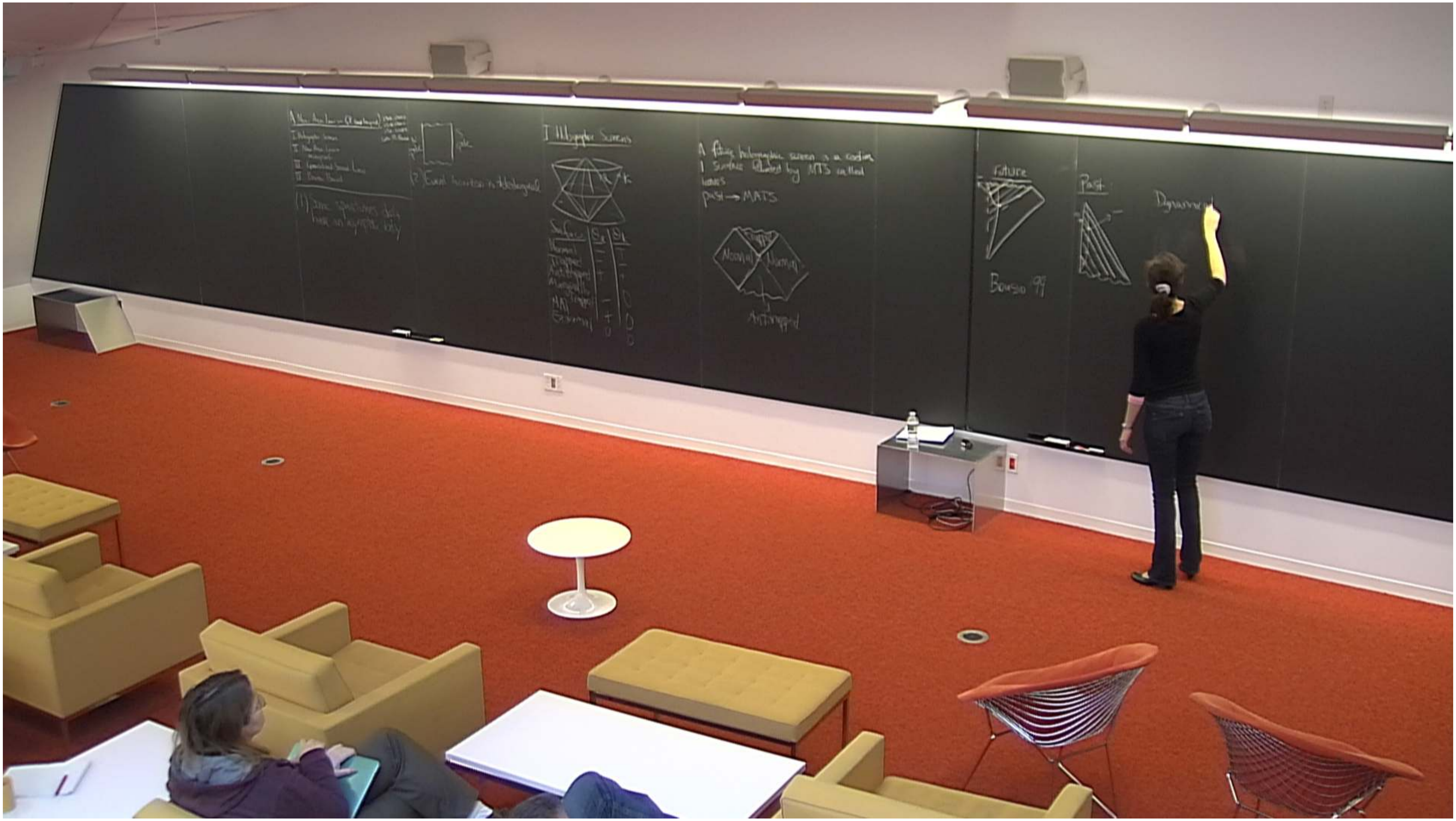

I Holographic Screens:
A future holographic screen is a codim 1 surface foliated by MTS called leaves
past → MATS
Surface | θ_ℓ | θ_k
Normal | − | +
Trapped | − | −
Antitrapped | + | +
Marginally Trapped | − | 0
MAT | + | 0
Extremal | 0 | 0
Trapped
Normal
Normal
Antitrapped

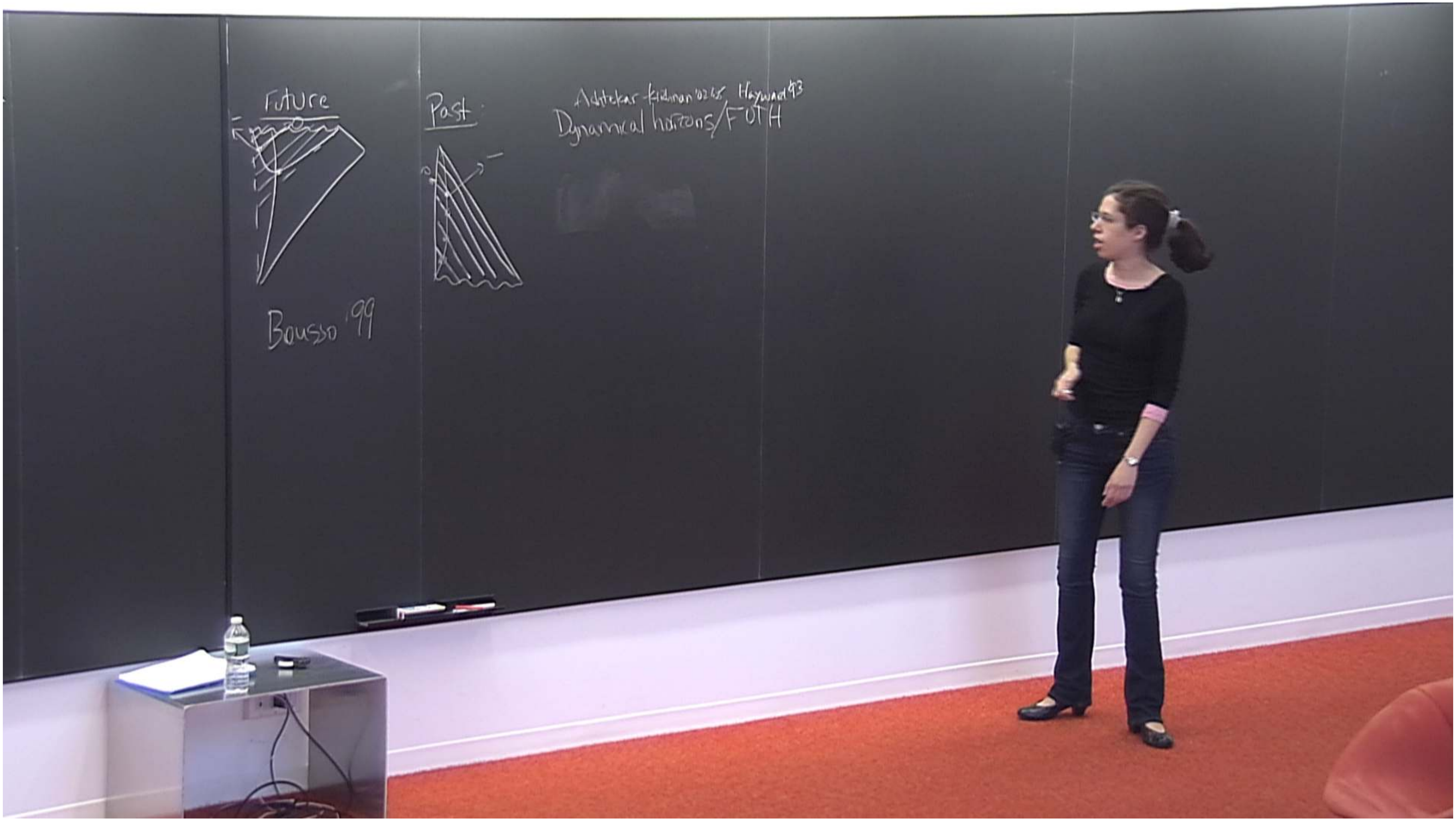

I Holographic Screens:
A future holographic screen is a codim
1 surface foliated by MTS called
leaves
past → MATS
Surface
Normal
Trapped
Antitrapped
Marginally Trapped
MAT
Extremal
Normal
Normal
Trapped
Antitrapped
Future


I Holographic Screens:
Surface θ_ℓ θ_k
Normal − +
Trapped − −
Antitrapped + +
Marginally Trapped − 0
MAT + 0
Extremal 0 0
A future holographic screen is a codim 1 surface foliated by MTS called leaves
past → MATS
Trapped
Normal Normal
Antitrapped
Future
Past

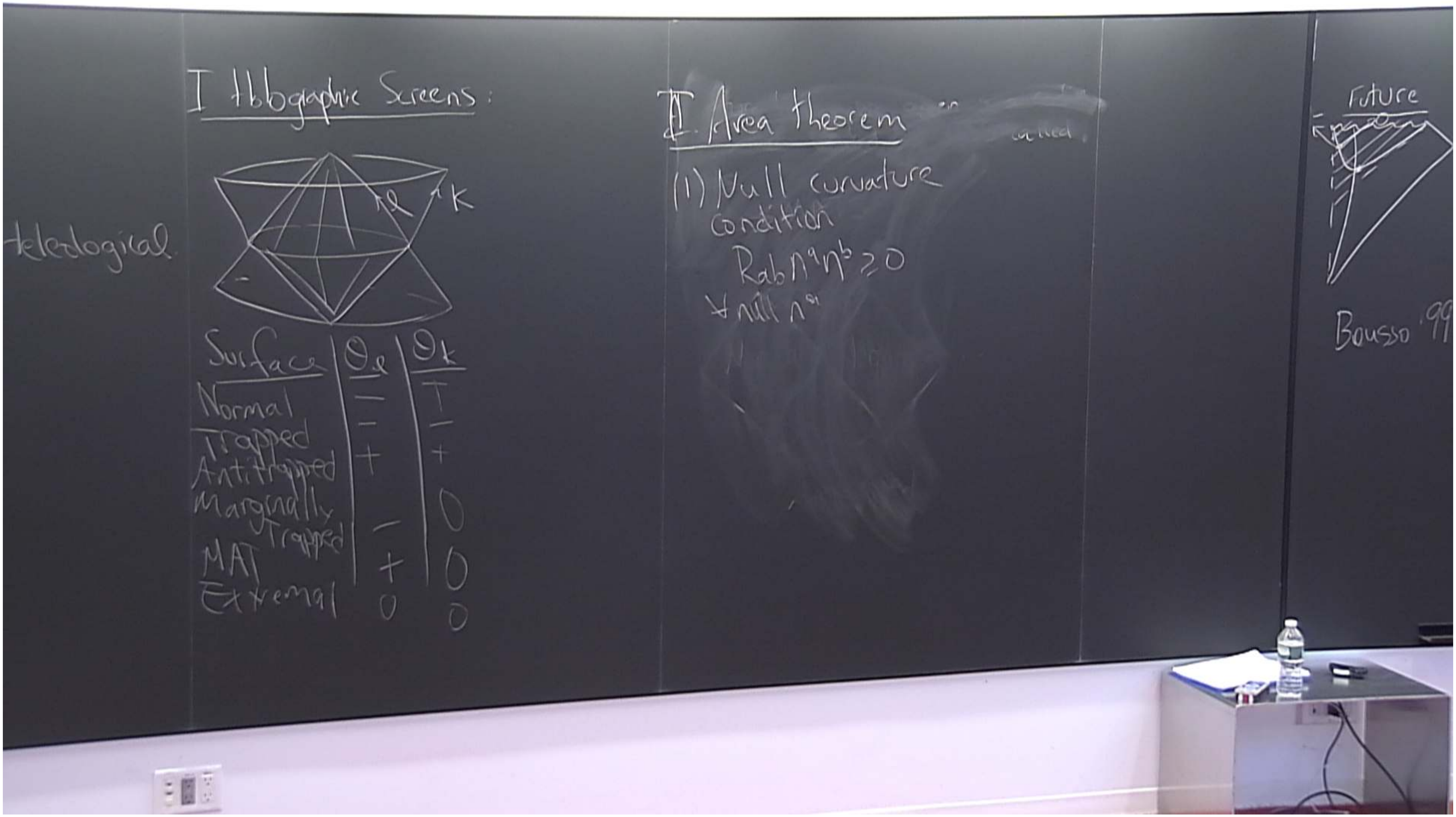

Future
Past

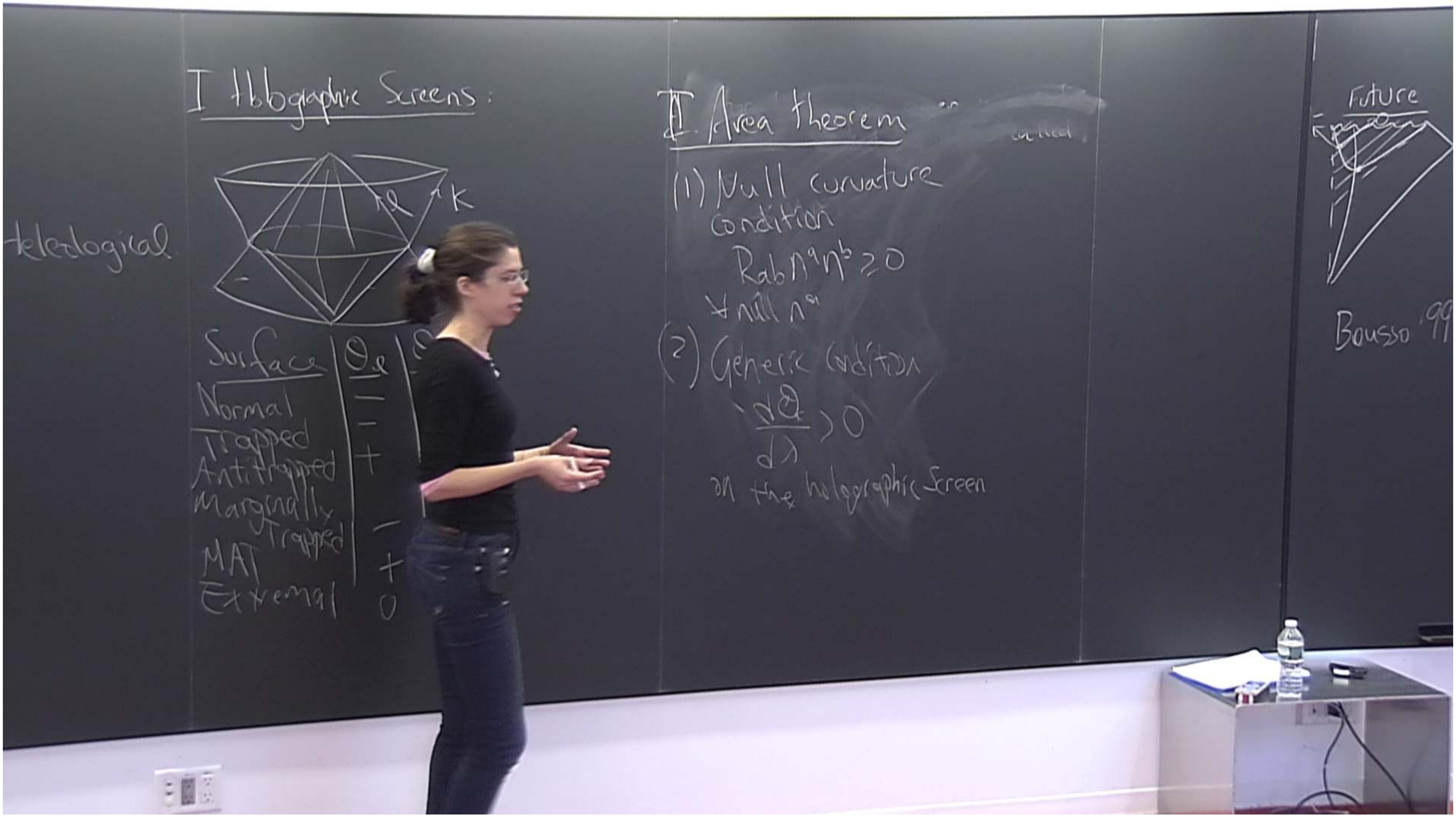

A New Area Law in GR (and beyond)
1504.07627
1504.07660
1511.02099
with R. Bousso
I Holographic Screens
II New Area Law + proof
III. Generalized Second Law
IV. Bousso Bound
(1) Some spacetimes don't have an asymptotic bdy.
N pole
S pole
(2) Event horizon is teleological
I Holographic Screens:
k
Surface
Normal
Trapped
Antitrapped
Marginally Trapped
MAT
Extremal
A future holographic
1 surface
leaves
past → MAT
Normal
Anti



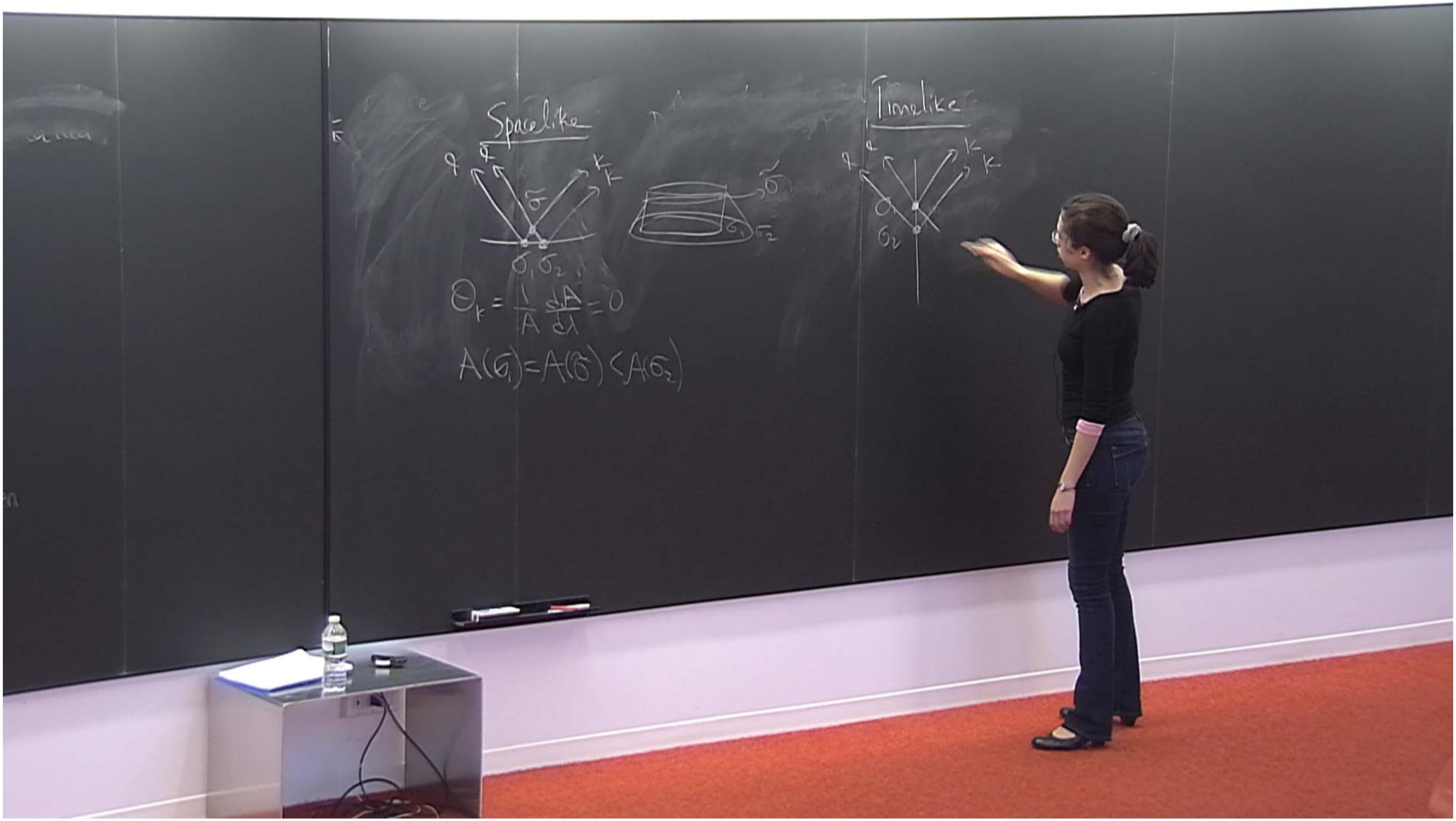

Future
Past
Bousso '99
Ashtekar-Krishnan '02 '03 Hayward '93
Dynamical horizons/FOTH


Future
Past
Ashtekar-Krishnan '02 '03, Hayward '93
Dynamical horizons/FOTH = spacelike future holographic screens
Timelike membranes - timelike future holographic screens
Bousso '99

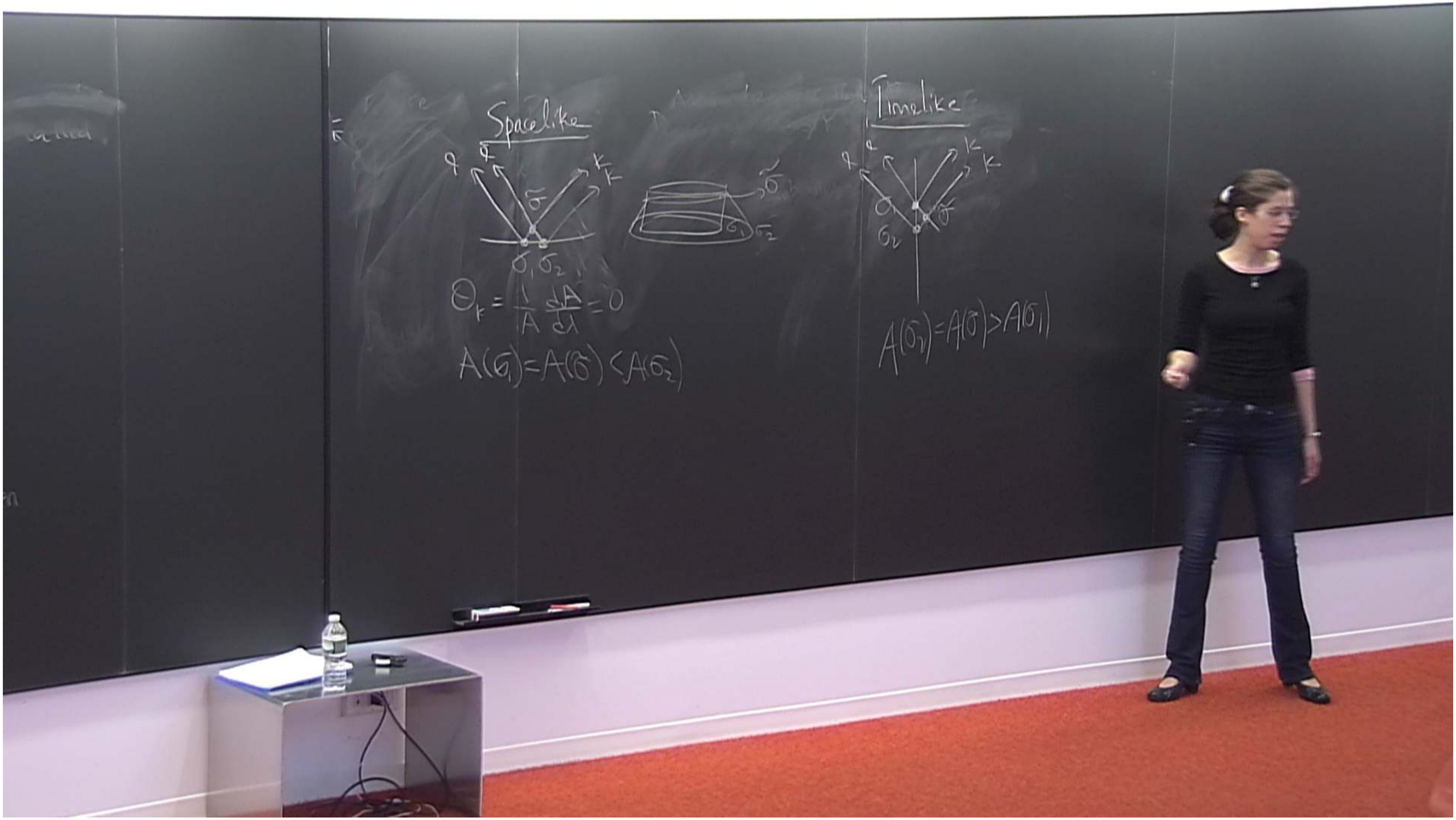

I Holographic Screens:
teleological
l
k
Surface | θ_l | θ_k
Normal | − | +
Trapped | − | −
Antitrapped | + | +
Marginally Trapped | − | 0
MAT | + | 0
Extremal | 0 | 0
II Area theorem
(1) Null curvature condition
$R_{ab} n^a n^b \geq 0$
$\forall$ null n^a
Future
Bousso '99

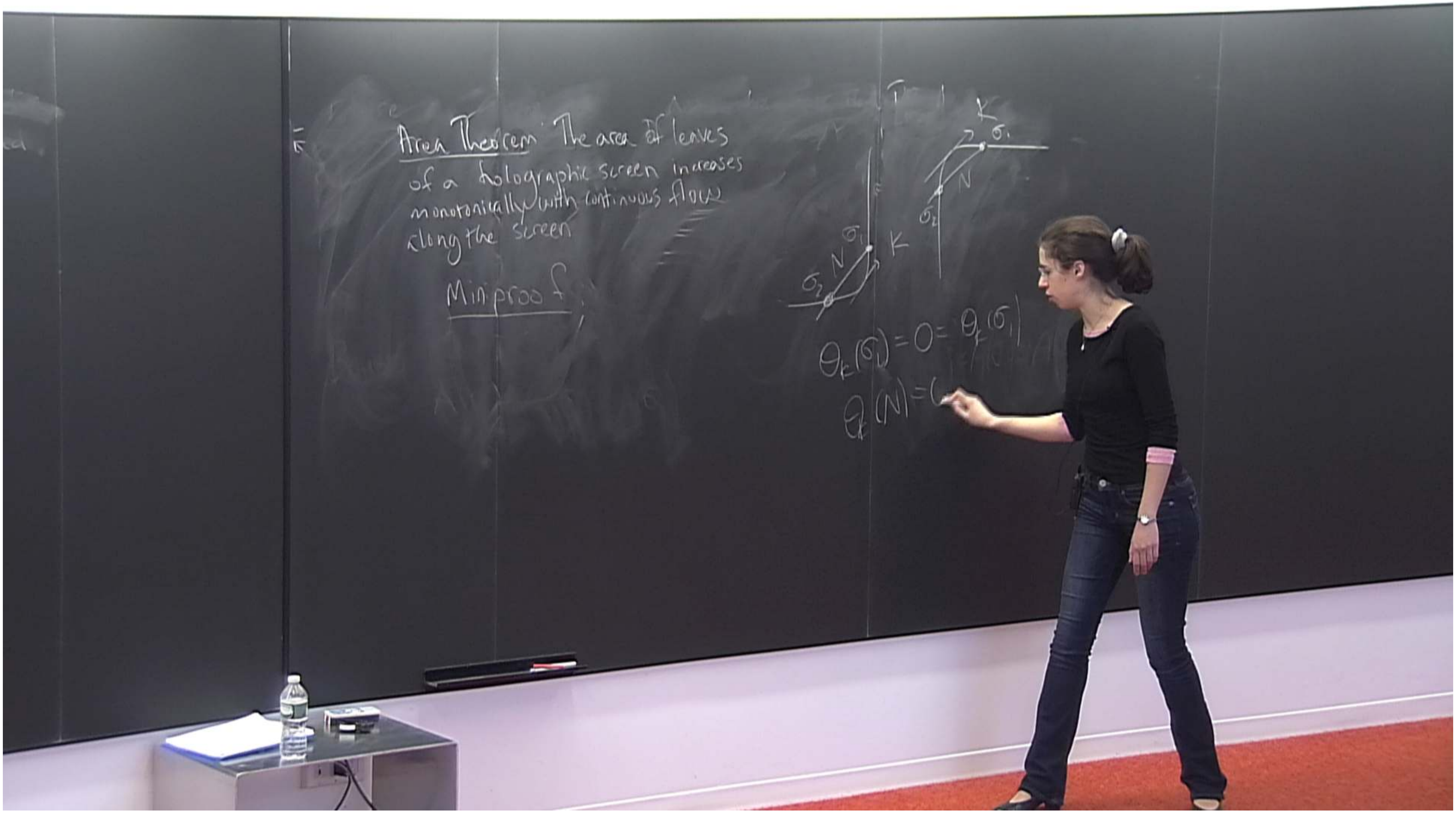

teleological
I Holographic Screens:
K
Surface
Normal
Trapped
Antitrapped
Marginally Trapped
MAT
Extremal
II Area theorem
(1) Null curvature condition
Rab n^a n^b ≥ 0
∀ null n^a
(2) Generic condition
dθ/dλ > 0
on the holographic screen
Future
Bousso '99

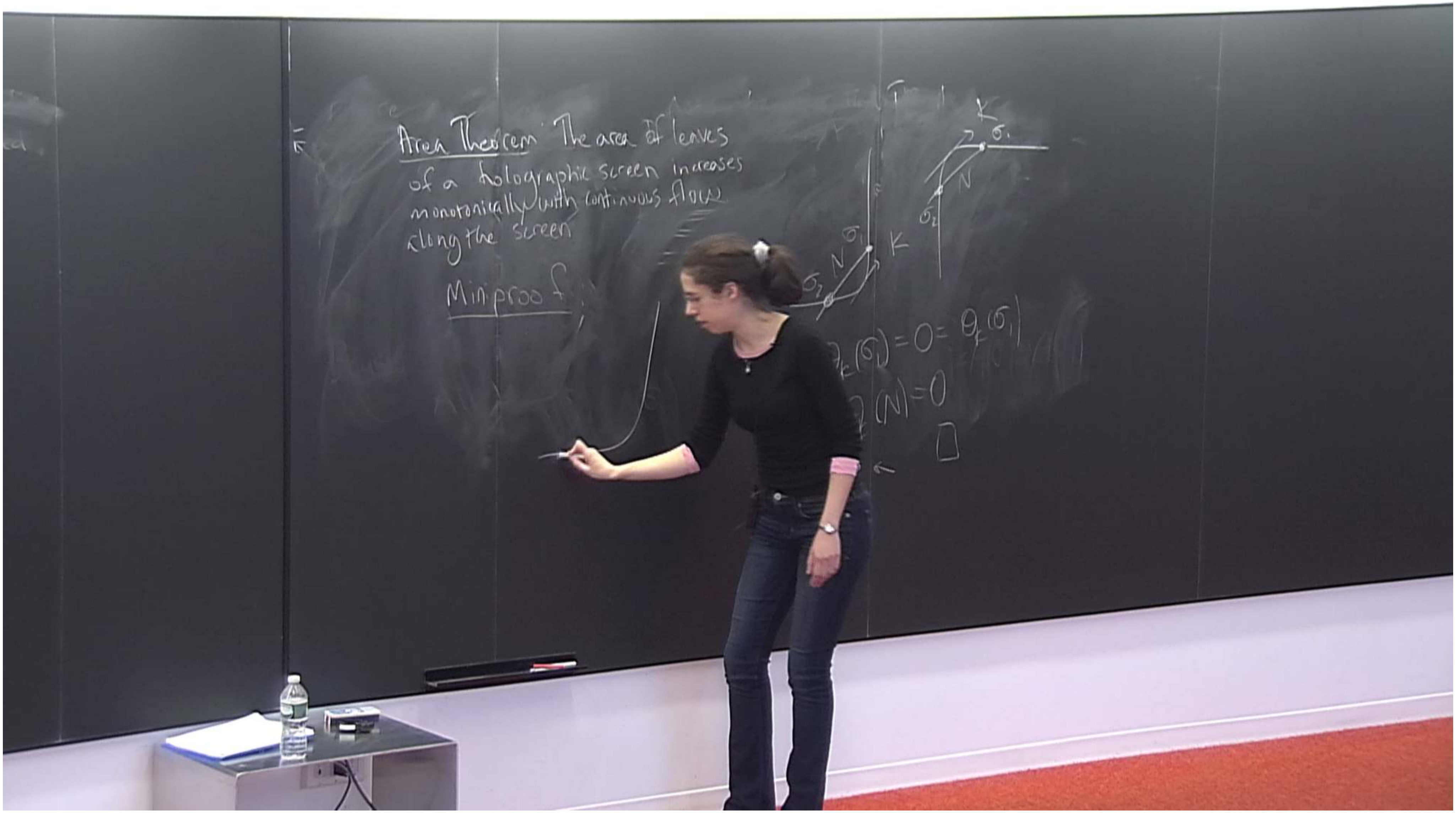

Spacelike



Spacelike
Timelike
$\Theta_k = \frac{1}{A}\frac{dA}{d\lambda} = 0$
$A(\sigma_1) = A(\tilde{\sigma}) < A(\sigma_2)$


Spacelike
Timelike
$\Theta_k = \frac{1}{A}\frac{dA}{d\lambda} = 0$
$A(\sigma_1) = A(\tilde{\sigma}) < A(\sigma_2)$
$A(\sigma_2) = A(\tilde{\sigma}) > A(\sigma_1)$


Area Theorem: The area of leaves
of a holographic screen increases
monotonically with continuous flow
along the screen
Mini proof
K
N
σ1
σ2


Area Theorem: The area of leaves
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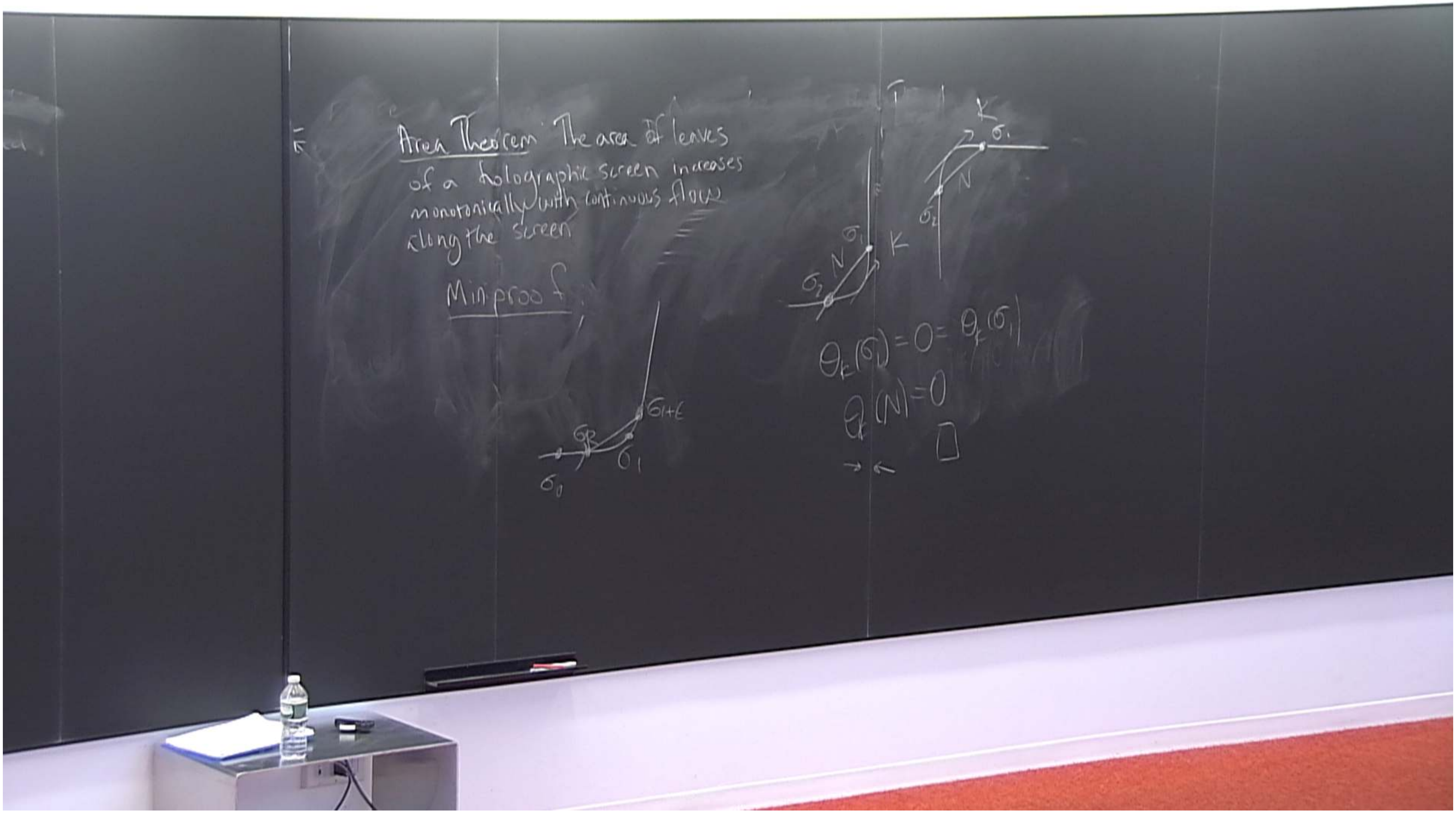
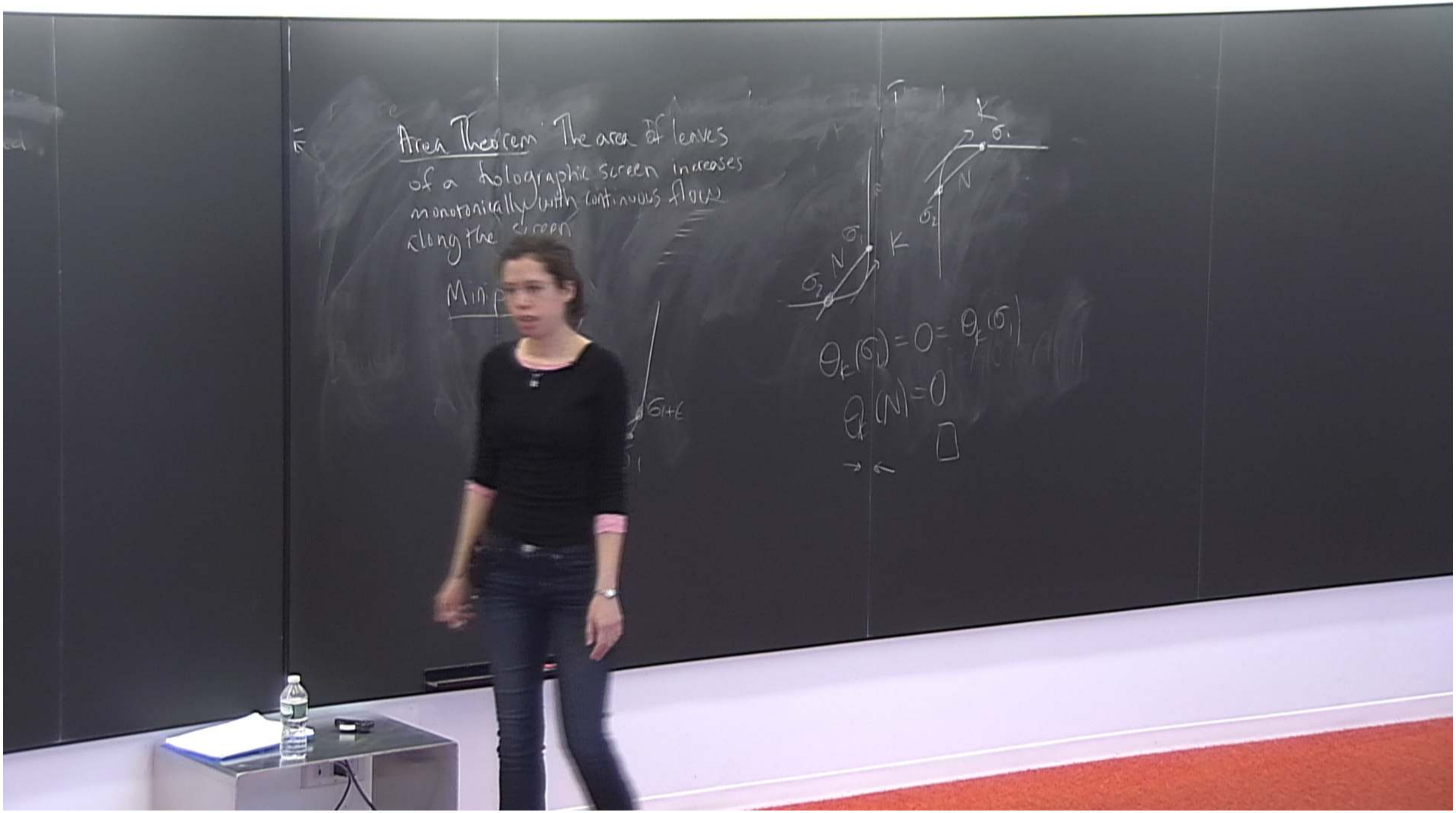
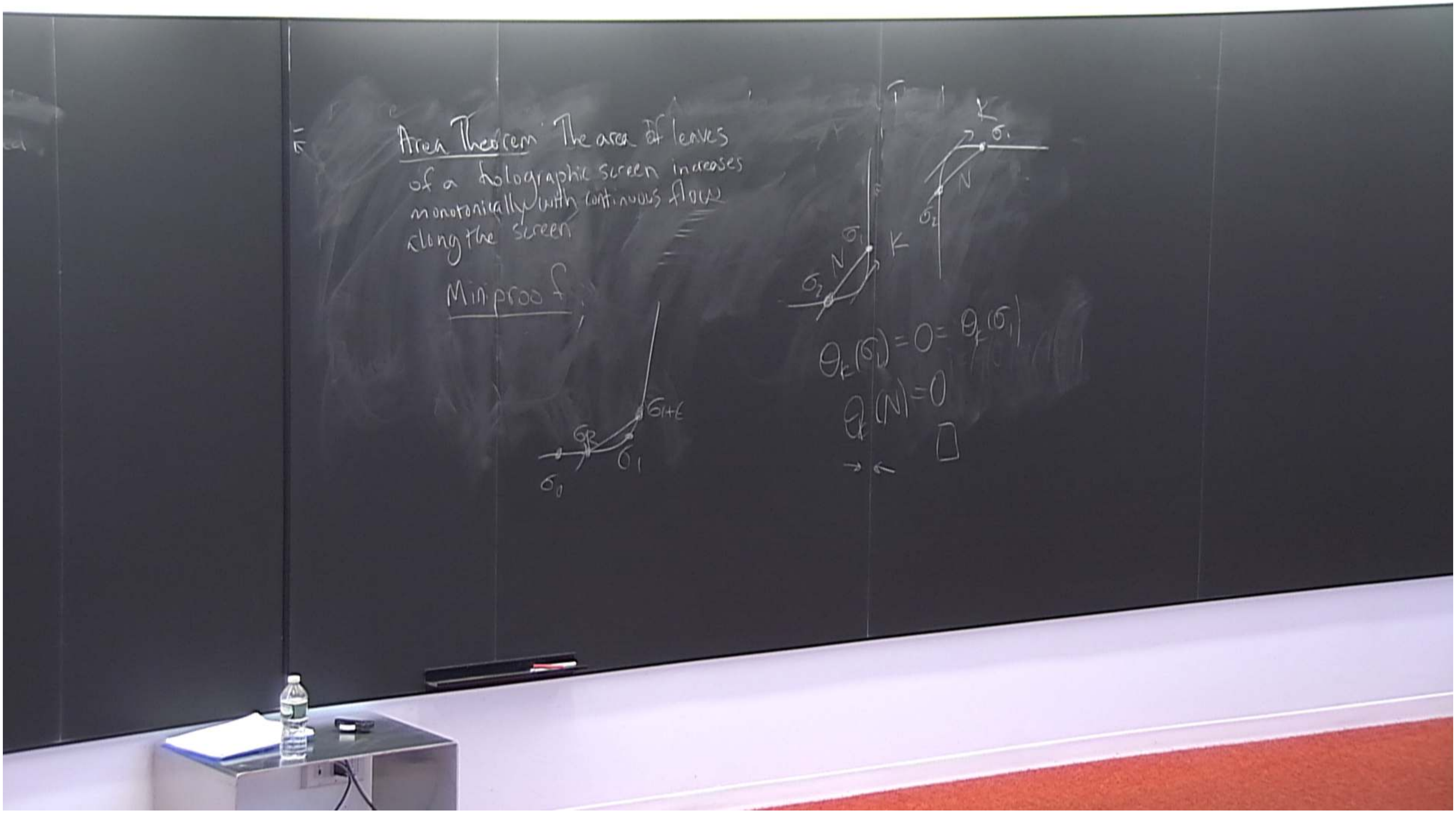
along the screen
Mini proof


Area Theorem: The area of leaves of a holographic screen increases monotonically with continuous flow along the screen
Mini proof
σ_0
σ_1
$\sigma_{1+\epsilon}$
N
K
σ_1
σ_2
$\theta_k(\sigma_2) = 0 = \theta_k(\sigma_1)$
$\theta_k(N) = 0$

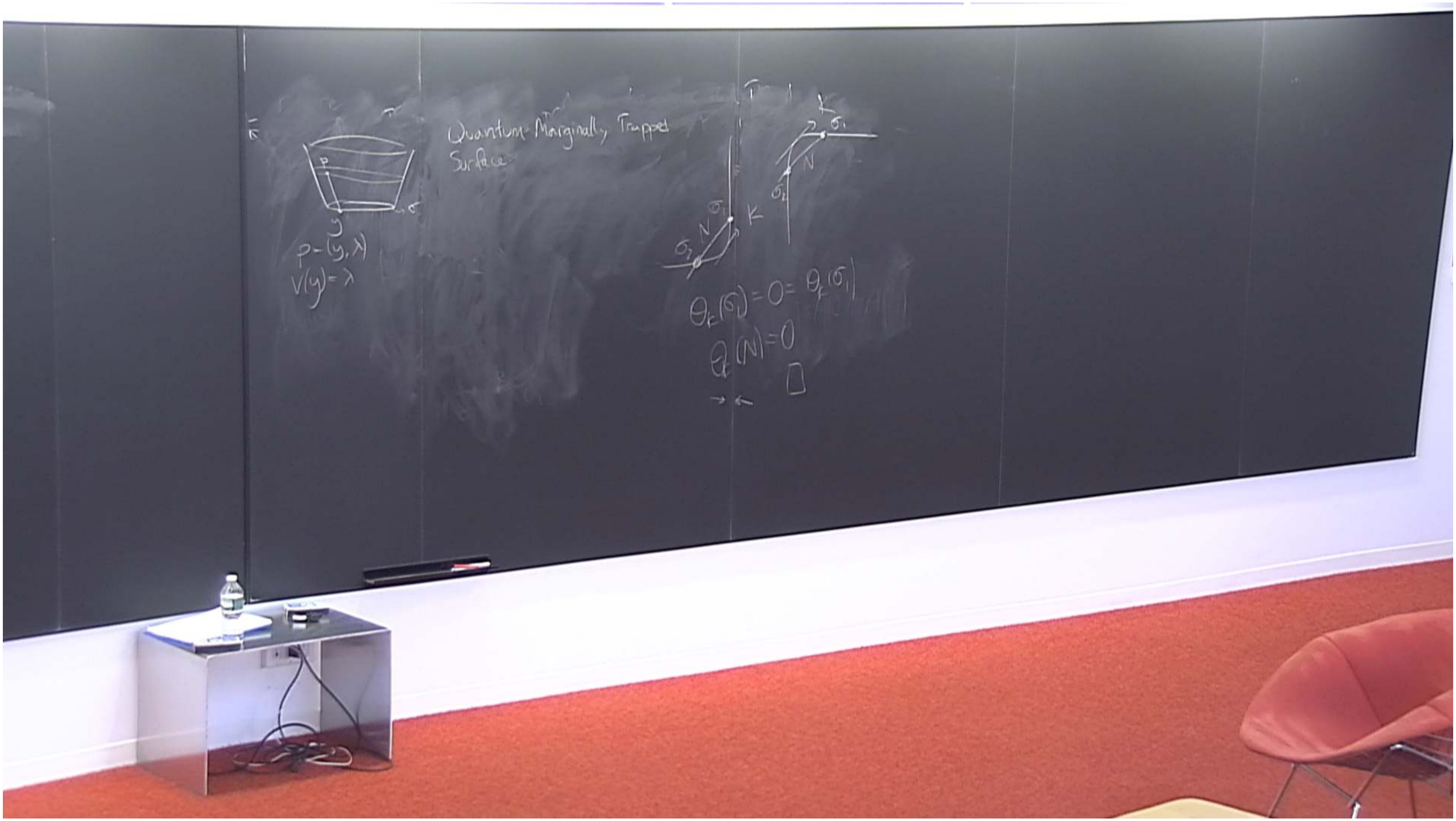

Area Theorem The area of leaves
of a holographic screen increases
monotonically with continuous flow
along the screen
Mini proof
$\theta_k(\sigma_2) = 0 = \theta_k(\sigma_1)$

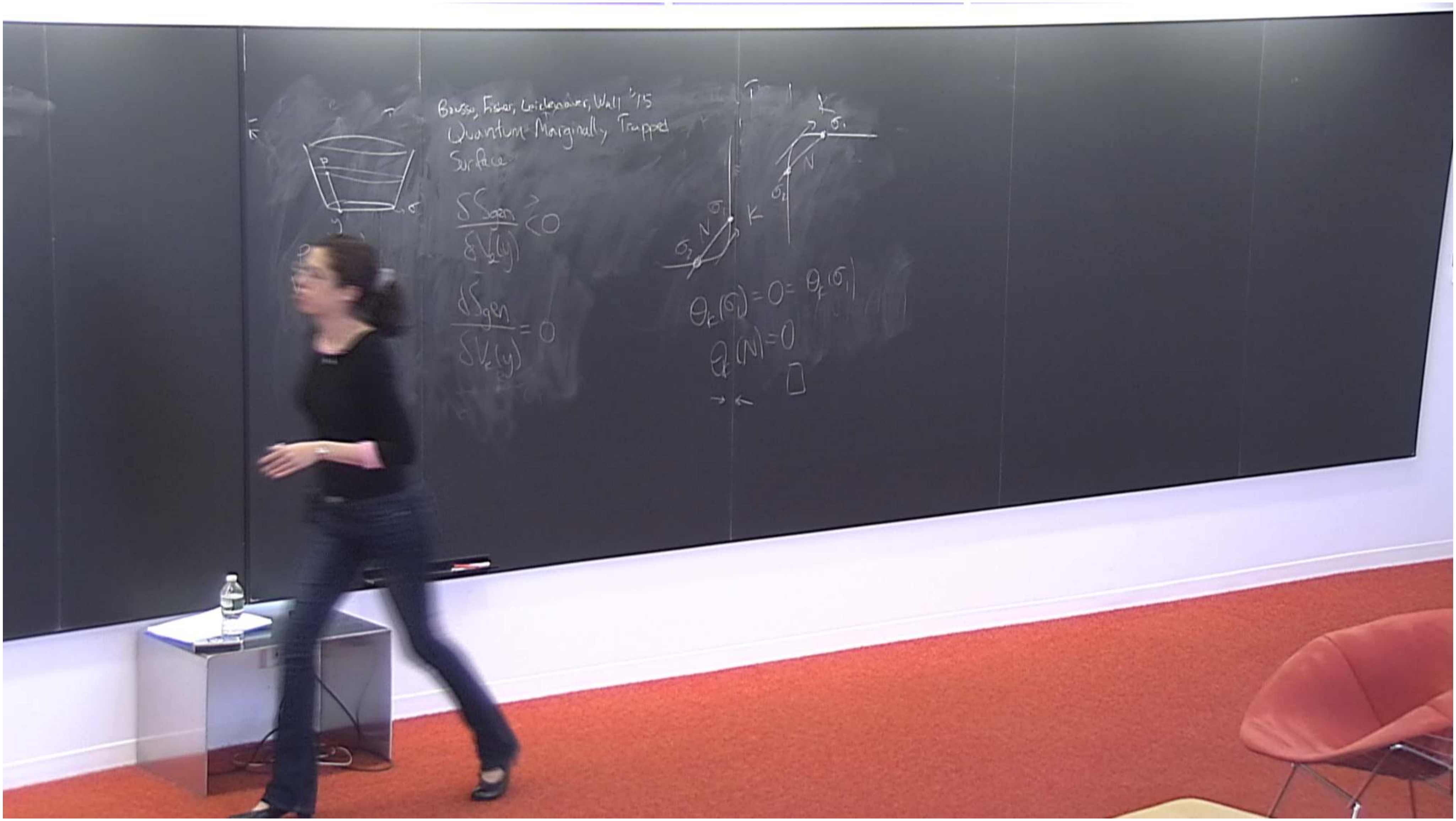

Area Theorem: The area of leaves of a holographic screen increases monotonically with continuous flow along the screen
$\theta_k(\sigma_2) = 0 = \theta_k(\sigma_1)$
$\theta_k(N) = 0$

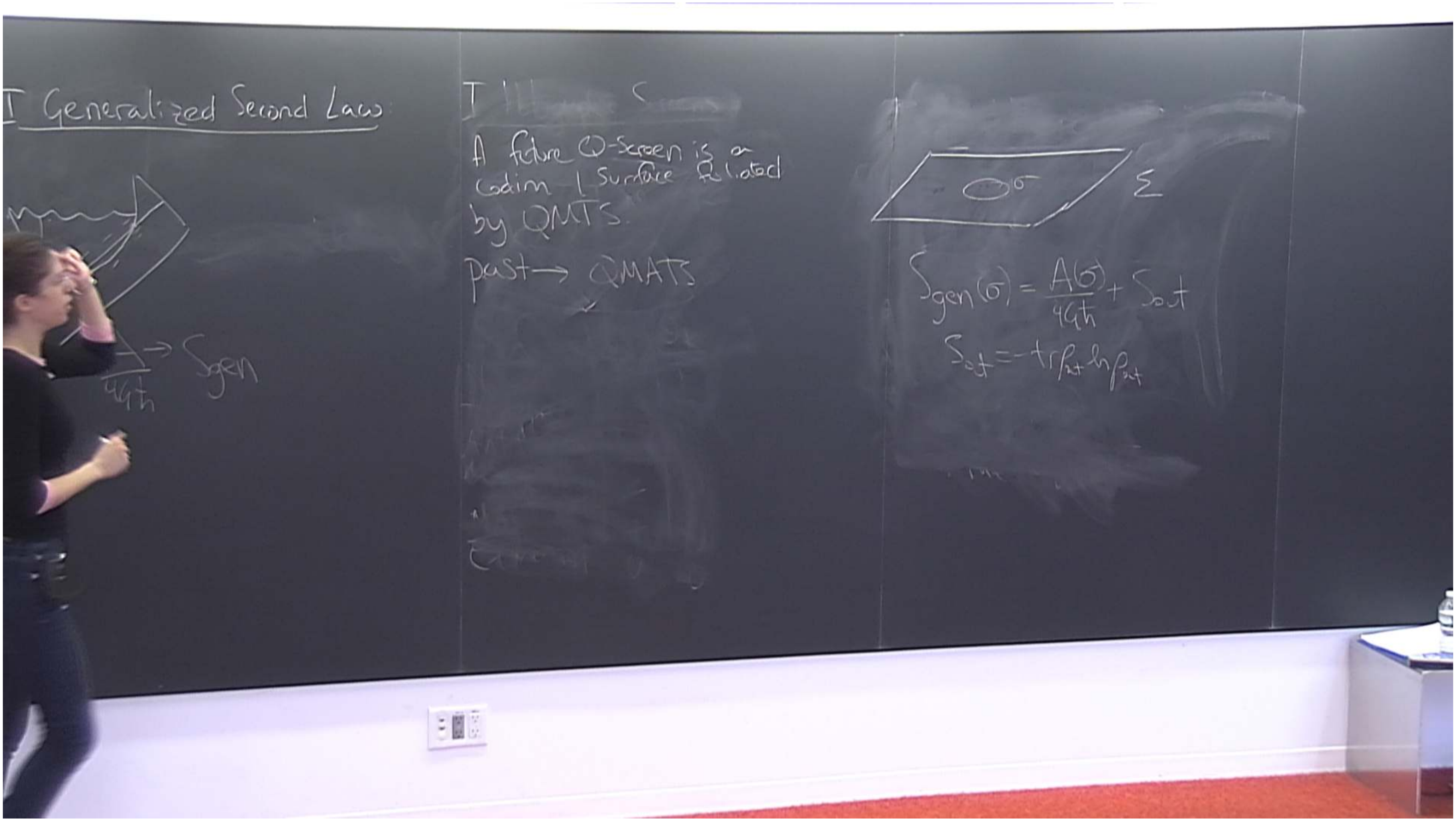

Area Theorem: The area of leaves
of a holographic screen increases
monotonically with continuous flow
along the screen
Mini proof

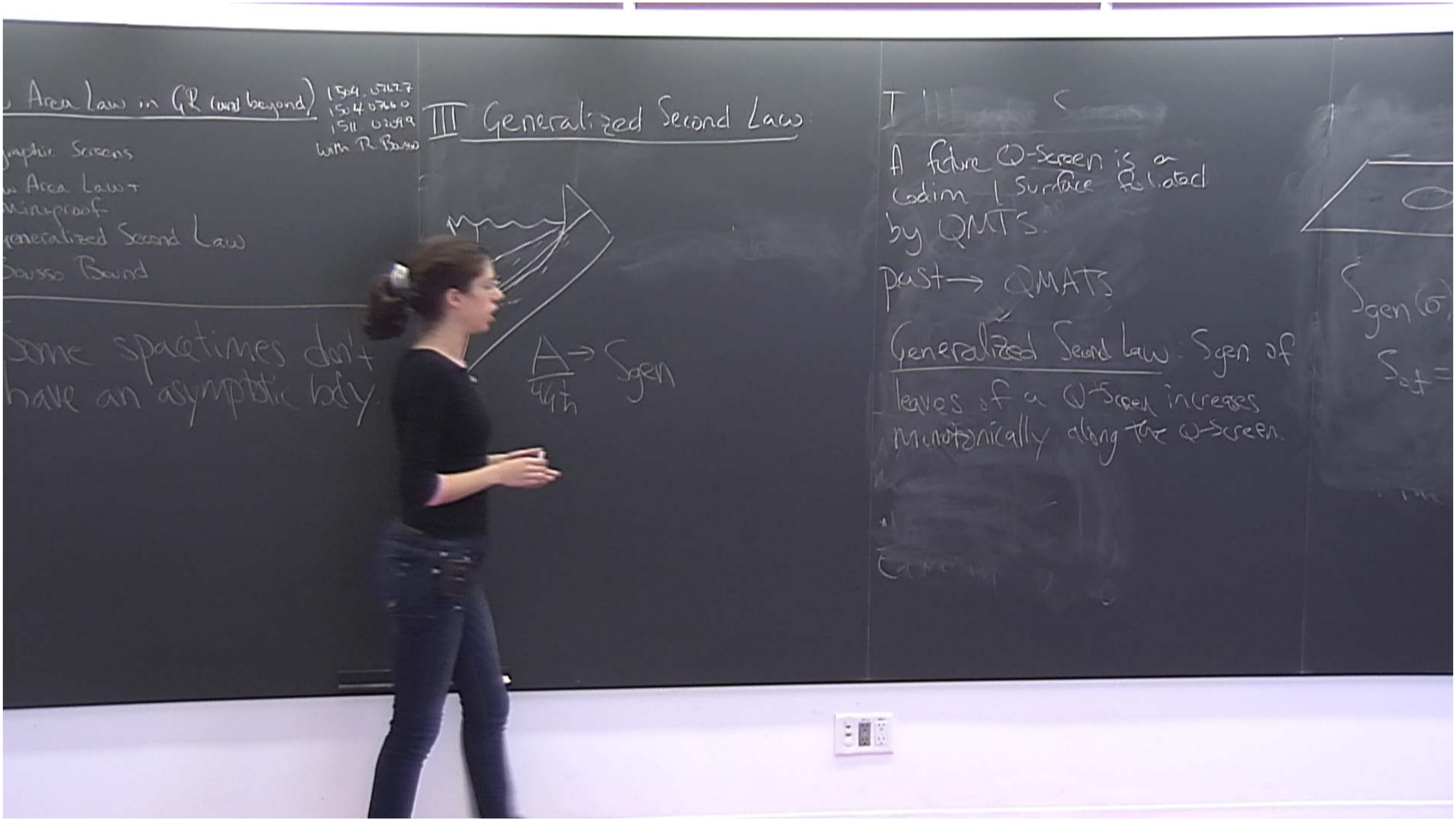

III Generalized Second Law
I Holographic Screens
II Area theorem
Bad
Good
K
Surface
Normal
Trapped
Antitrapped
Marginally Trapped
MAT
Extremal

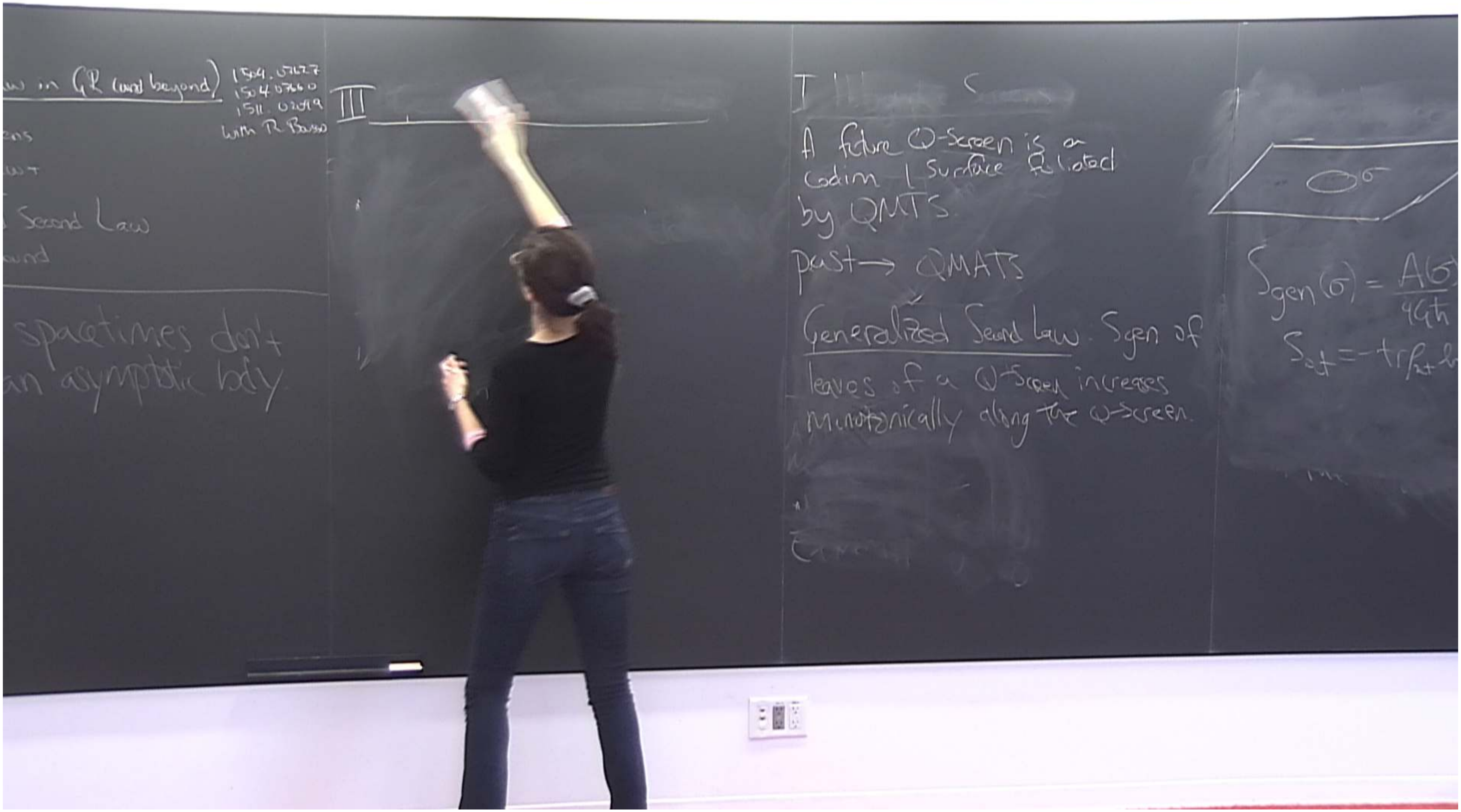
N
K
σ_1
σ_2
$\Theta_k(\sigma_2) = 0 = \Theta_k(\sigma_1)$
$\Theta_k(N) = 0$


Quantum Marginally Trapped
Surface
p - (y, λ)
V(y) = λ
Θ_k(σ_2) = 0 = Θ_k(σ_1)
Θ_ℓ(N) = 0

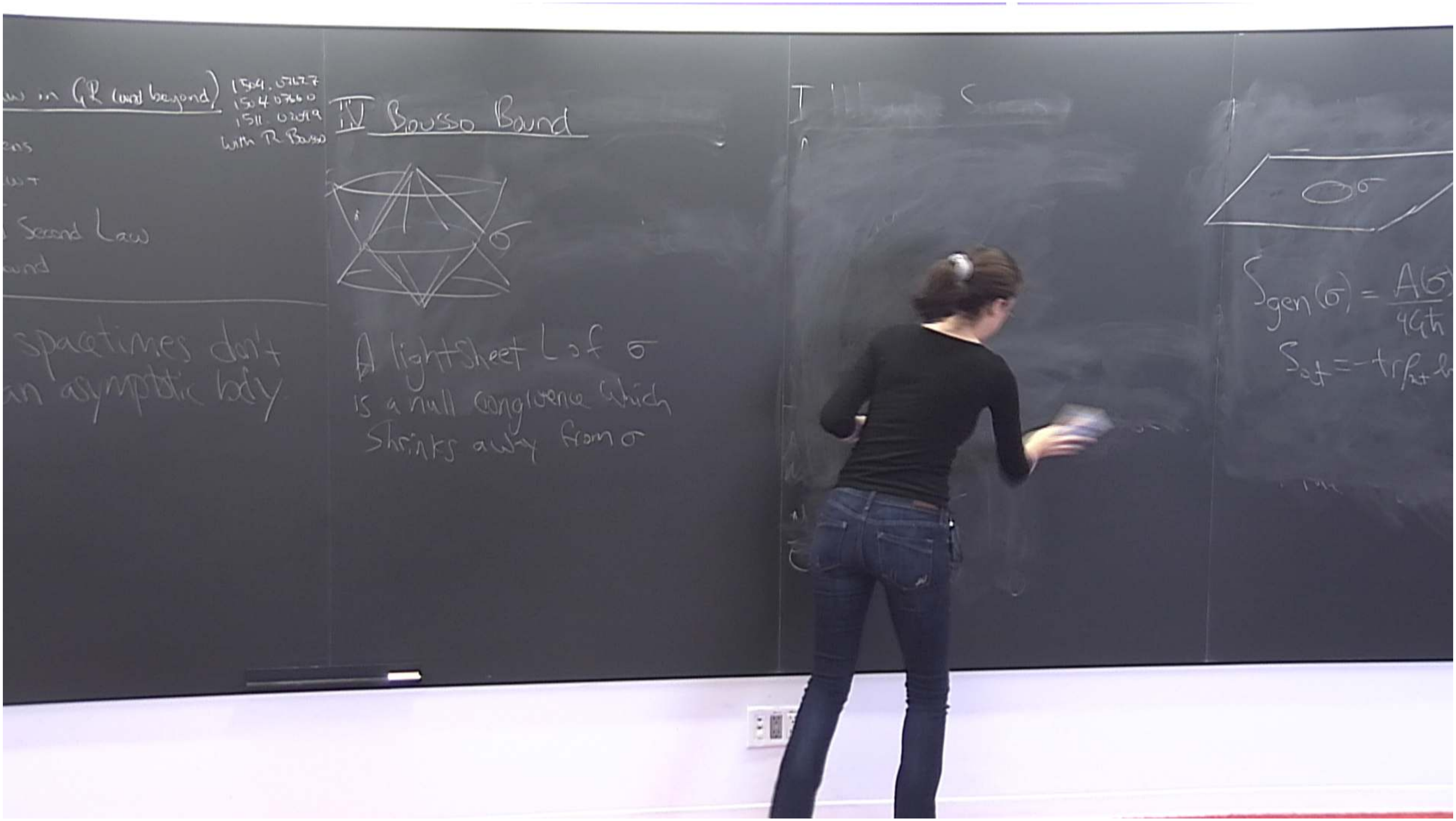

Bousso, Fisher, Leichenauer, Wall '15
Quantum Marginally Trapped
Surface


I Generalized Second Law
Sgen
4Għ
A future Q-Screen is a codim 1 surface foliated by QMTS.
past → QMATS
Σ
σ
Sgen(σ) = A(σ)/4Għ + Sout
Sout = -tr ρout ln ρout

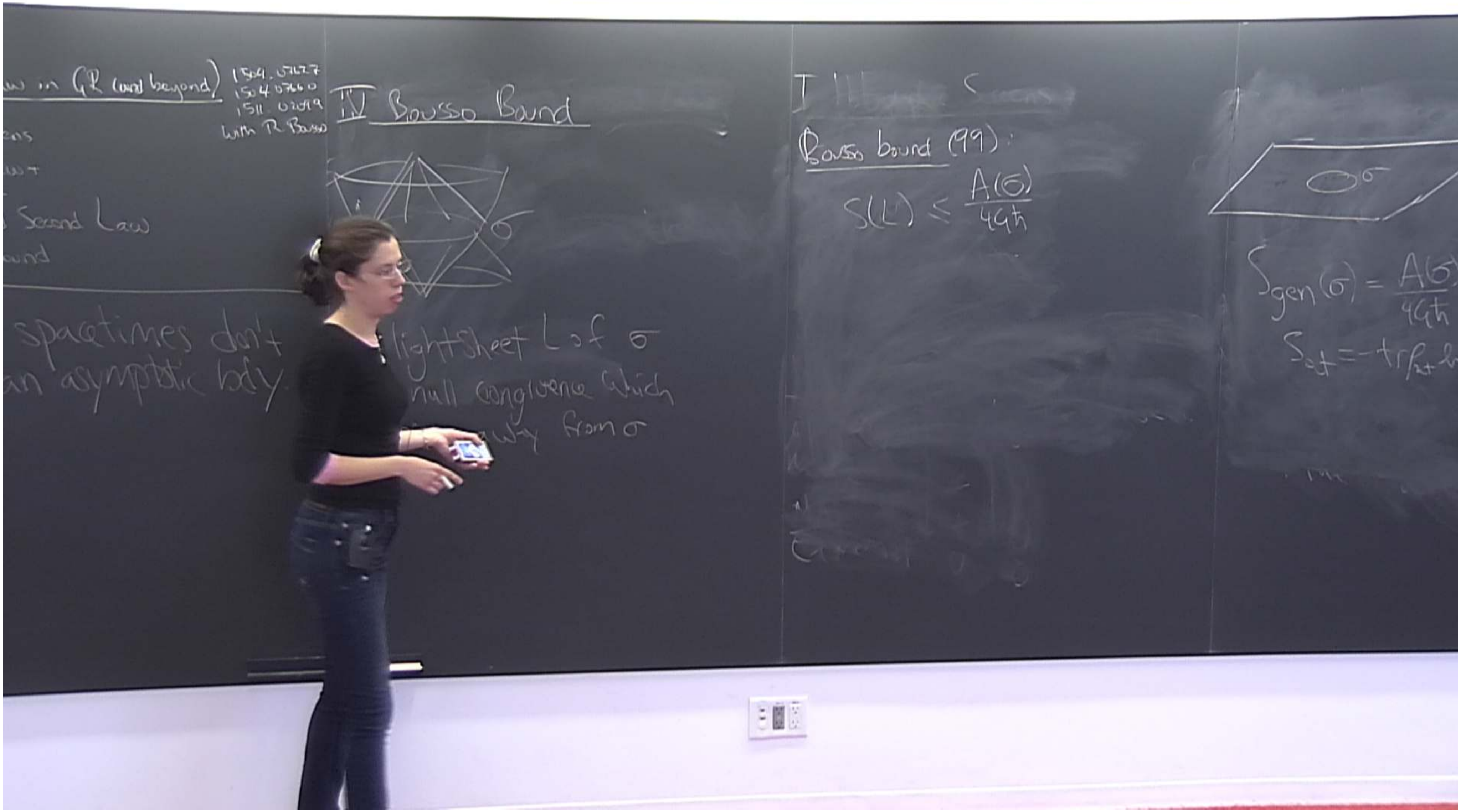

Area Law in GR (and beyond)
1504.07627
1504.07660
1511.02099
with R. Bousso
Area Law
Generalized Second Law
Bousso Bound
Some spacetimes don't have an asymptotic bdy.
III Generalized Second Law
A → Sgen
A future Q-Screen is a codim 1 surface foliated by QMTS.
past → QMATS
Generalized Second Law: Sgen of leaves of a Q-Screen increases monotonically along the Q-Screen.

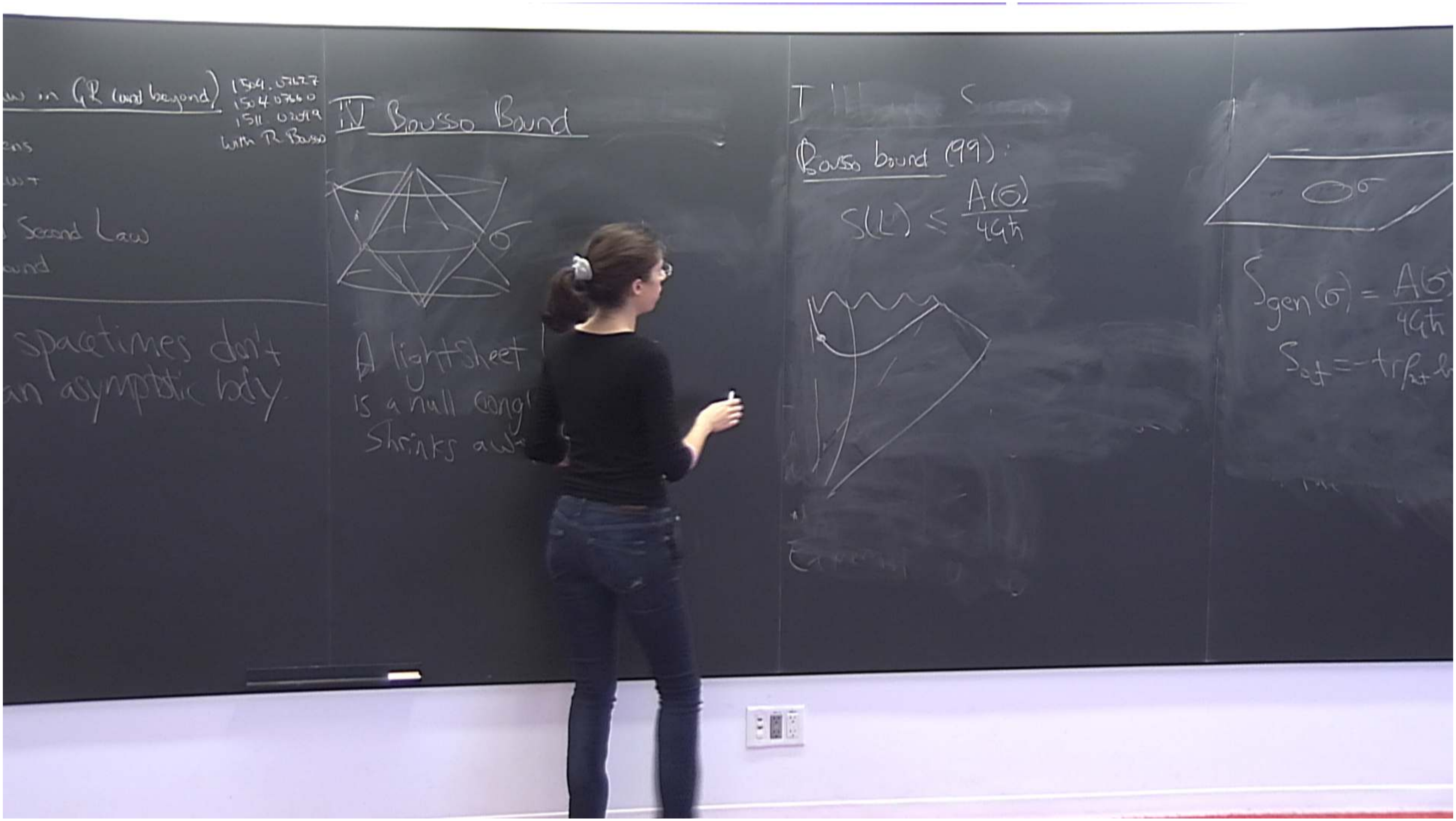

w in GR (and beyond)
1504.07627
1504.07660
1511.02099
with R. Bousso
III
Second Law
spacetimes don't
an asymptotic bdy
A future Q-Screen is a
codim 1 surface foliated
by QMTS.
past → QMATS
Generalized Second Law: Sgen of
leaves of a Q-Screen increases
monotonically along the Q-screen.
σ
Sgen(σ) =
4Għ

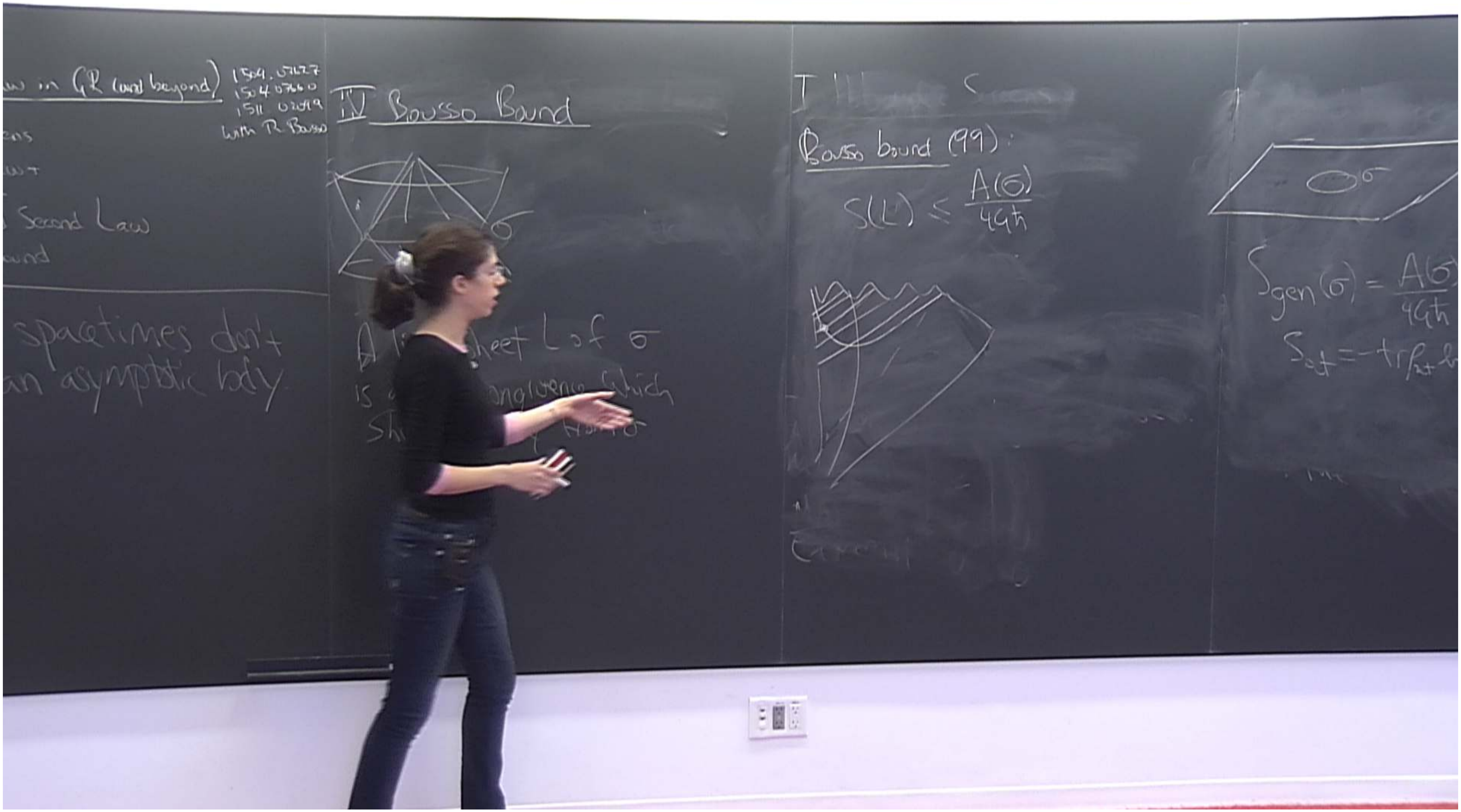
GR (and beyond)
1504.07627
1504.07660
1511.02099
with R. Bousso
Second Law
spacetimes don't
an asymptotic bdy.
IV Bousso Bound
A future Q-Screen is a
codim 1 surface foliated
by QMTS.
QMATS
Second Law. Sgen of
of a Q-Screen increases
along the Q-screen.



IV Bousso Bound
A lightsheet L of σ
is a null congruence which
shrinks away from σ
Second Law
with R. Bousso
spacetimes don't
an asymptotic body


GR (and beyond)
with R. Bousso
Second Law
spacetimes don't
an asymptotic bdy.
IV Bousso Bound
lightsheet L of σ
null congruence which
from σ
Bousso bound (99):
S(L) ≤ A(σ)/4Għ
σ
Sgen(σ) = A(σ)/4Għ


IV Bousso Bound
1504.07627
1504.07660
1511.02099
with R. Bousso
Second Law
spacetimes don't
an asymptotic bdy
A lightsheet
is a null cong
Shrinks aw
Bousso bound (99):
$S(L) \leq \frac{A(\sigma)}{4G\hbar}$
$S_{gen}(\sigma) = \frac{A(\sigma)}{4G\hbar}$



Bousso Bound
Bousso bound (99):
S(L) ≤ A(σ)/4Għ
Second Law
spacetimes don't
an asymptotic bdy.
with R. Bousso