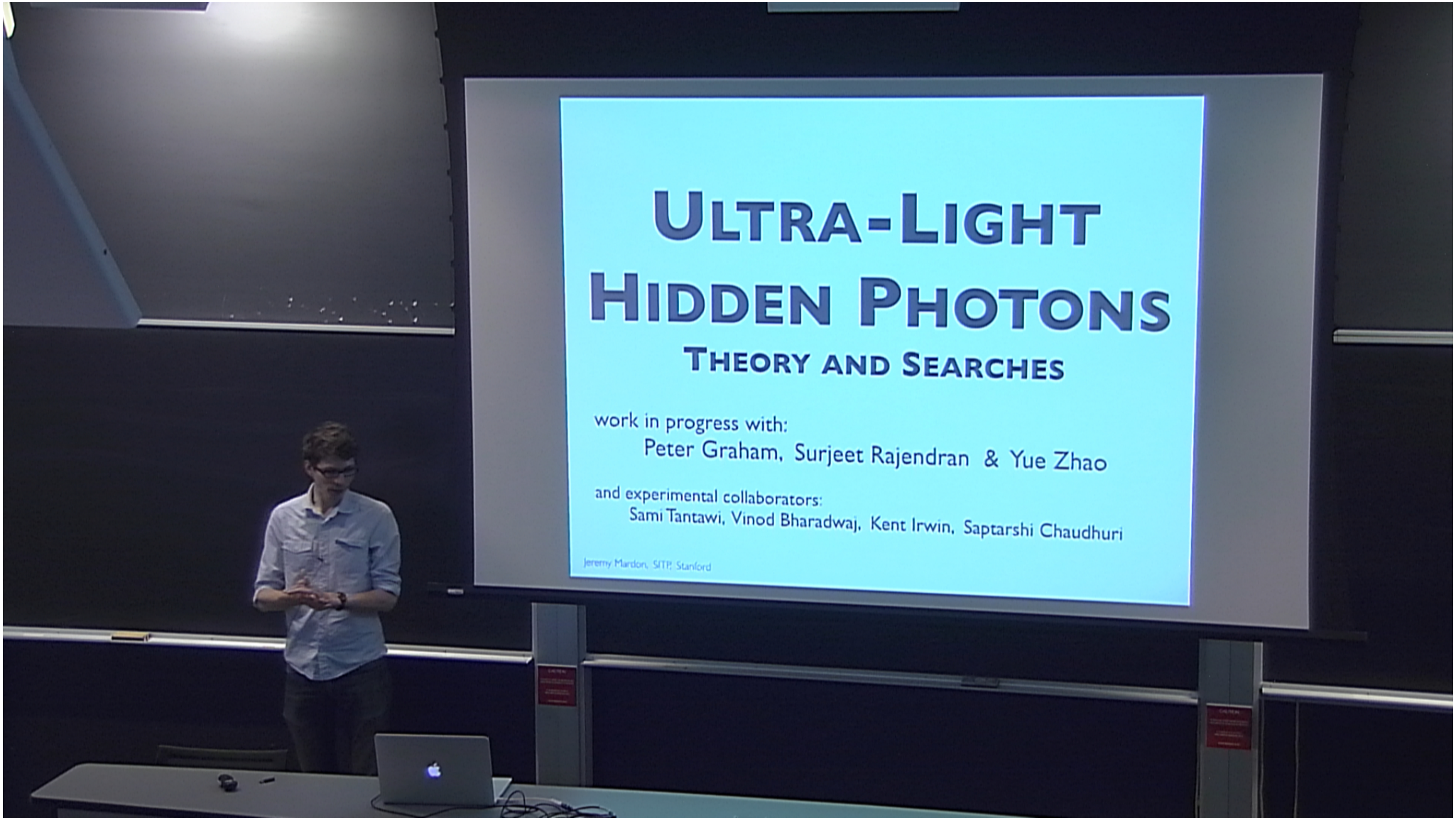
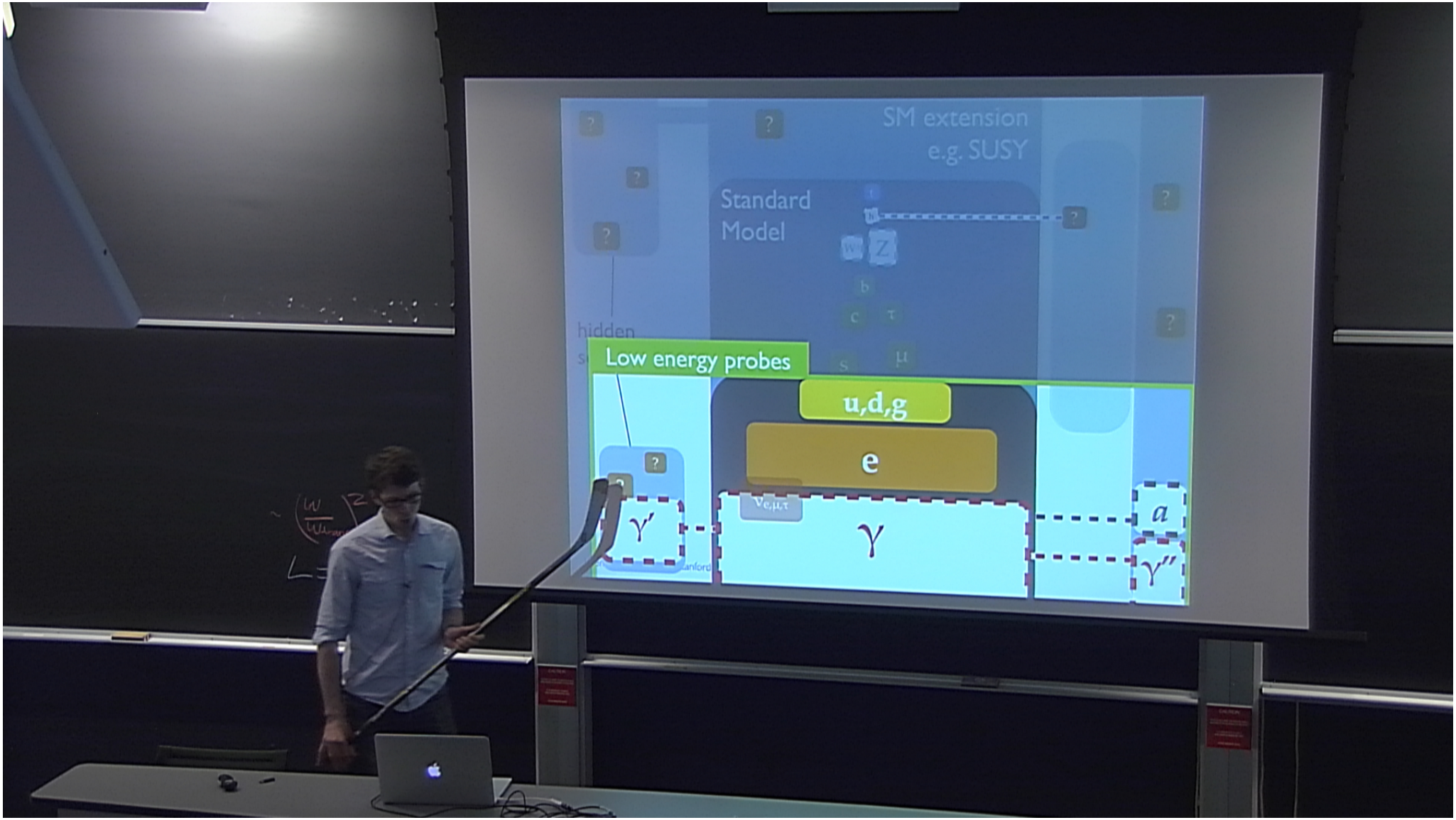
Title: Ultra-light hidden photons

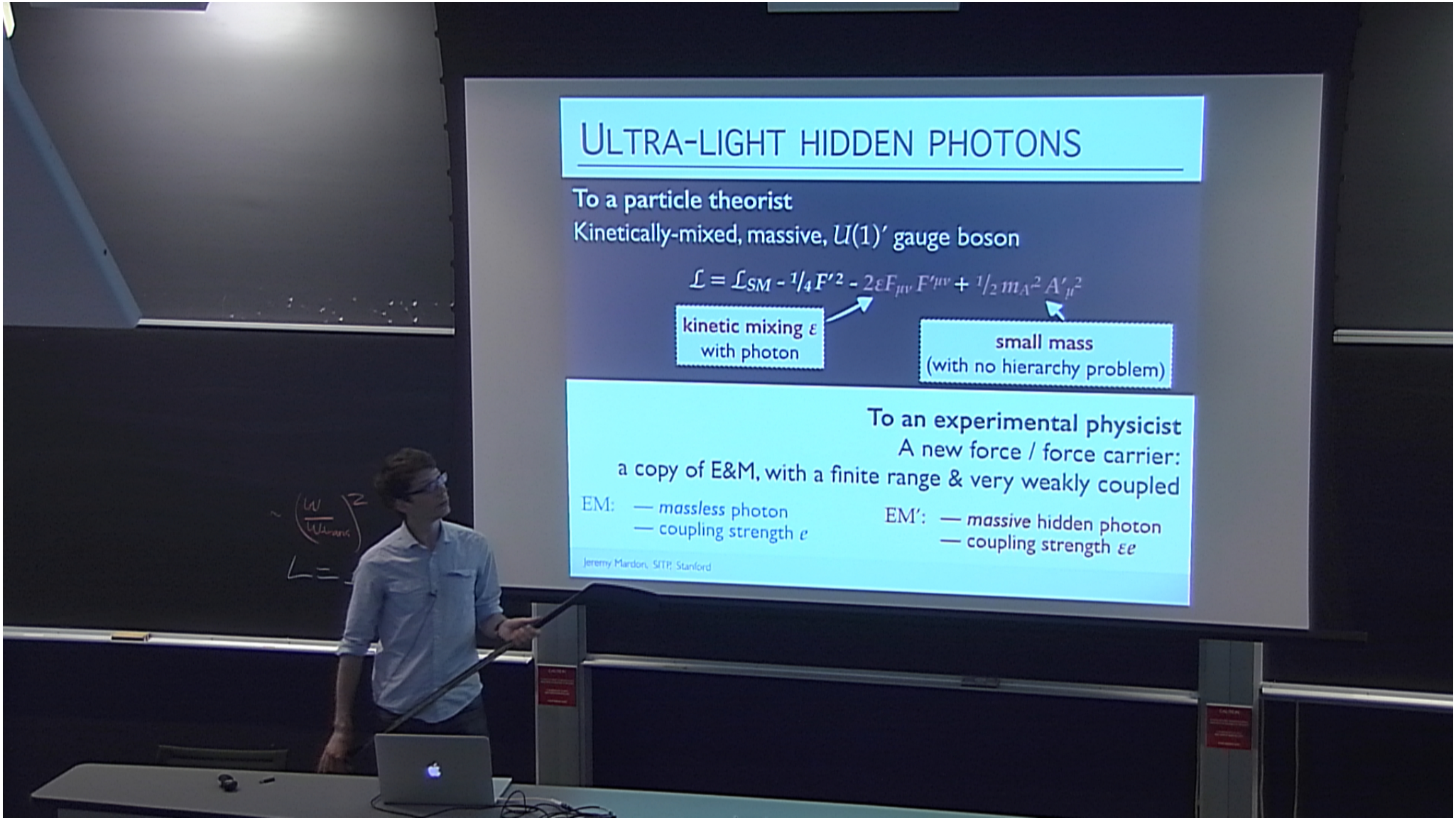
Date: Jun 18, 2014 04:30 PM

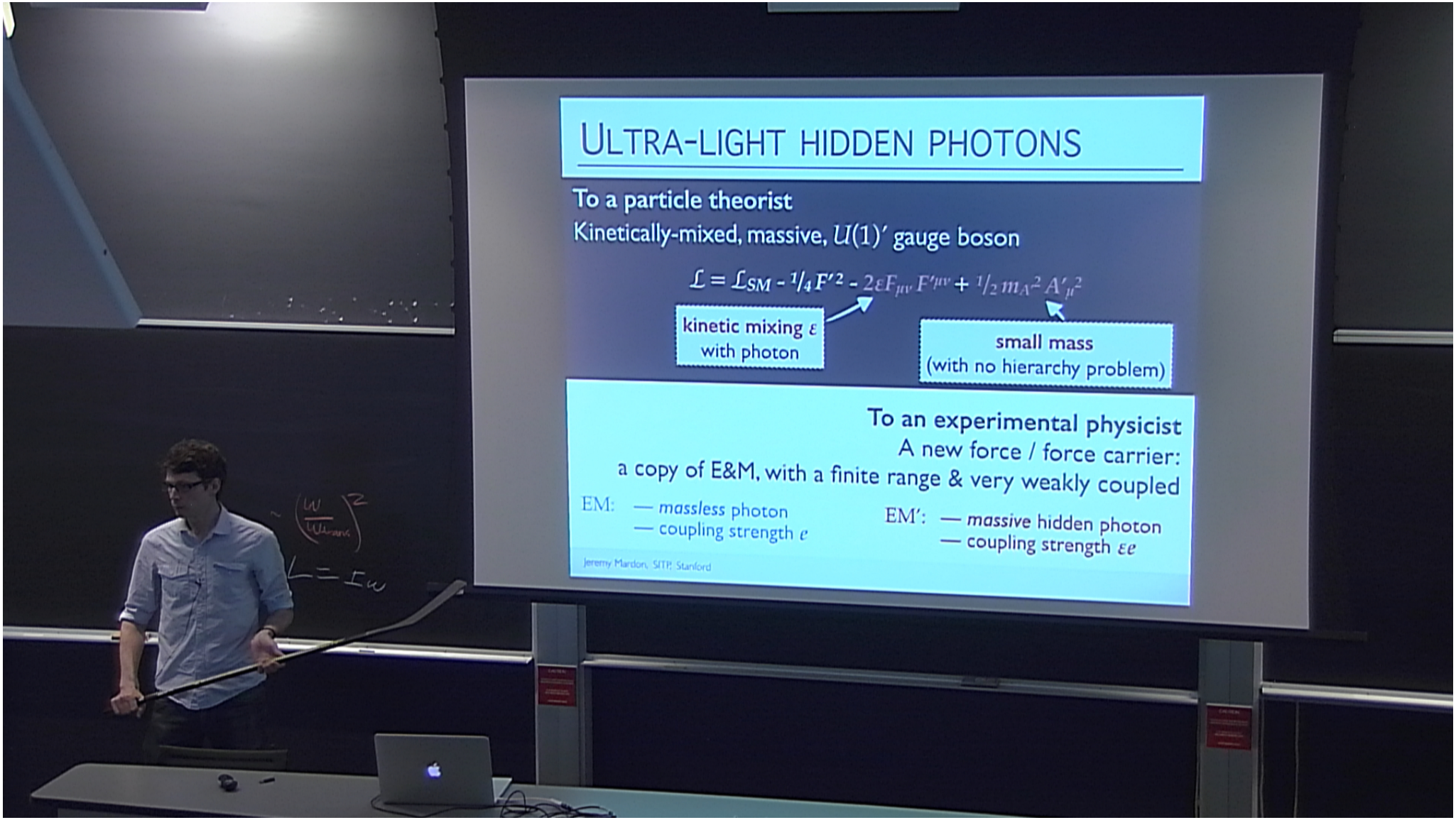
URL: http://pirsa.org/14060029

Abstract:


ULTRA-LIGHT
HIDDEN PHOTONS
THEORY AND SEARCHES
work in progress with:
Peter Graham, Surjeet Rajendran & Yue Zhao
and experimental collaborators:
Sami Tantawi, Vinod Bharadwaj, Kent Irwin, Saptarshi Chaudhuri
Jeremy Mardon, SITP, Stanford


SM extension
e.g. SUSY
Standard
Model
hidden
Low energy probes
u,d,g
e
$\nu_{e,\mu,\tau}$
γ'
γ
a
γ''


ULTRA-LIGHT HIDDEN PHOTONS
To a particle theorist
Kinetically-mixed, massive, U(1)′ gauge boson
$\mathcal{L} = \mathcal{L}_{SM} - \frac{1}{4}F'^2 - 2\varepsilon F_{\mu\nu}F'^{\mu\nu} + \frac{1}{2}m_{A'}^2 A'^2_\mu$
kinetic mixing ε with photon
small mass (with no hierarchy problem)
To an experimental physicist
A new force / force carrier:
a copy of E&M, with a finite range & very weakly coupled
EM: — massless photon — coupling strength e
EM′: — massive hidden photon — coupling strength εe
Jeremy Mardon, SITP, Stanford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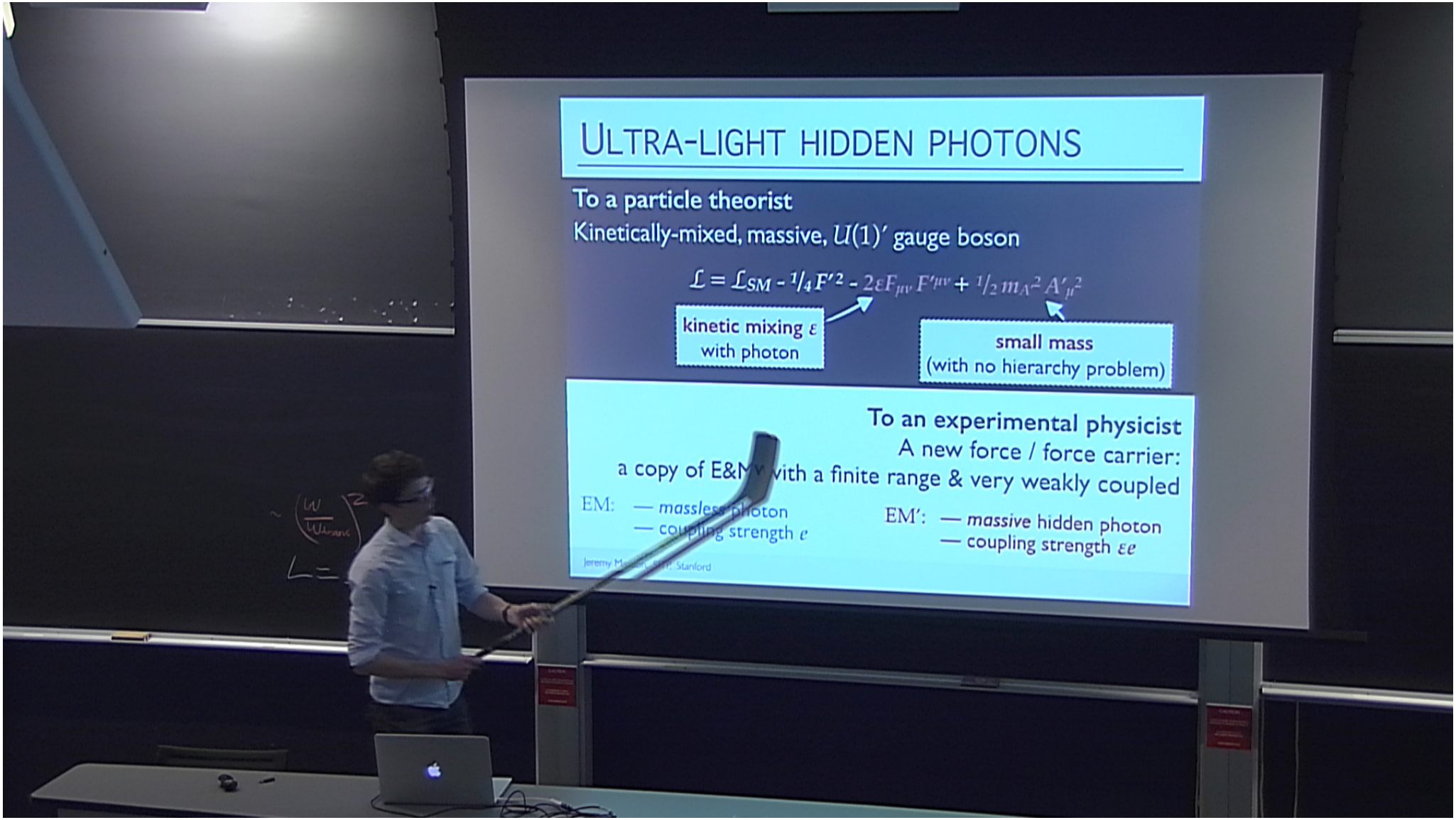
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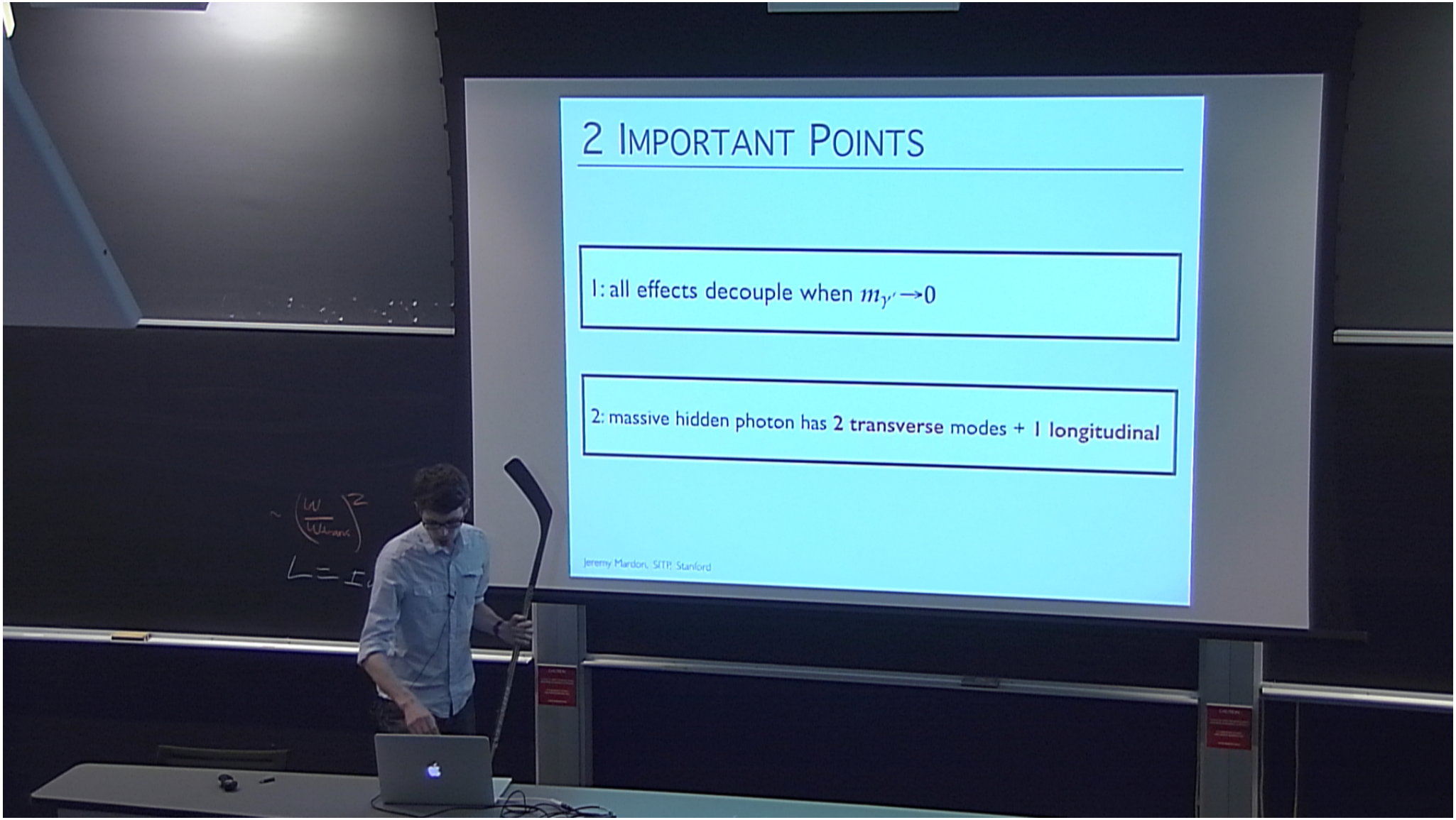
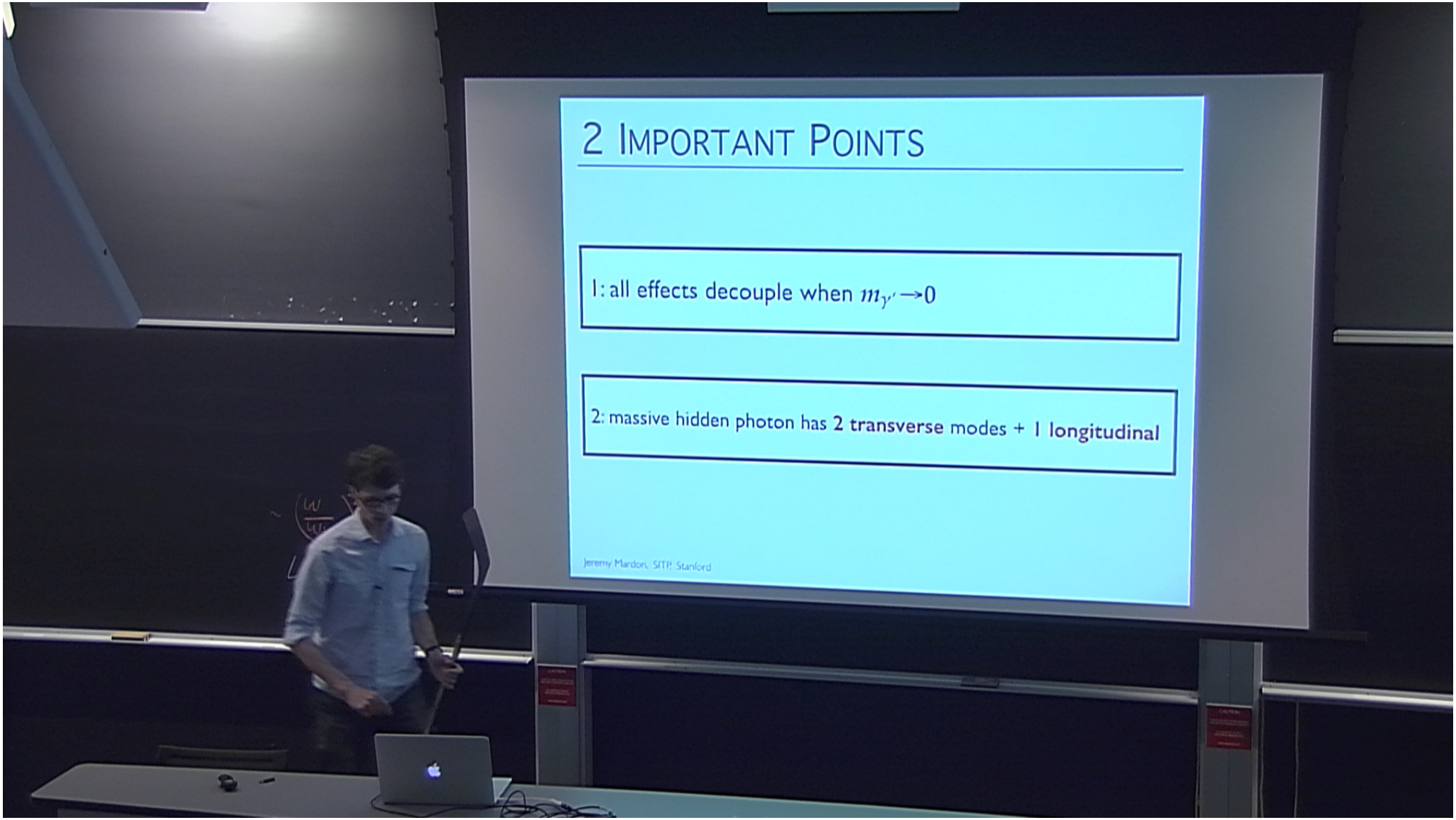

2 IMPORTANT POINTS
1: all effects decouple when $m_{\gamma'} \to 0$
2: massive hidden photon has 2 transverse modes + 1 longitudinal
Jeremy Mardon, SITP, Stanford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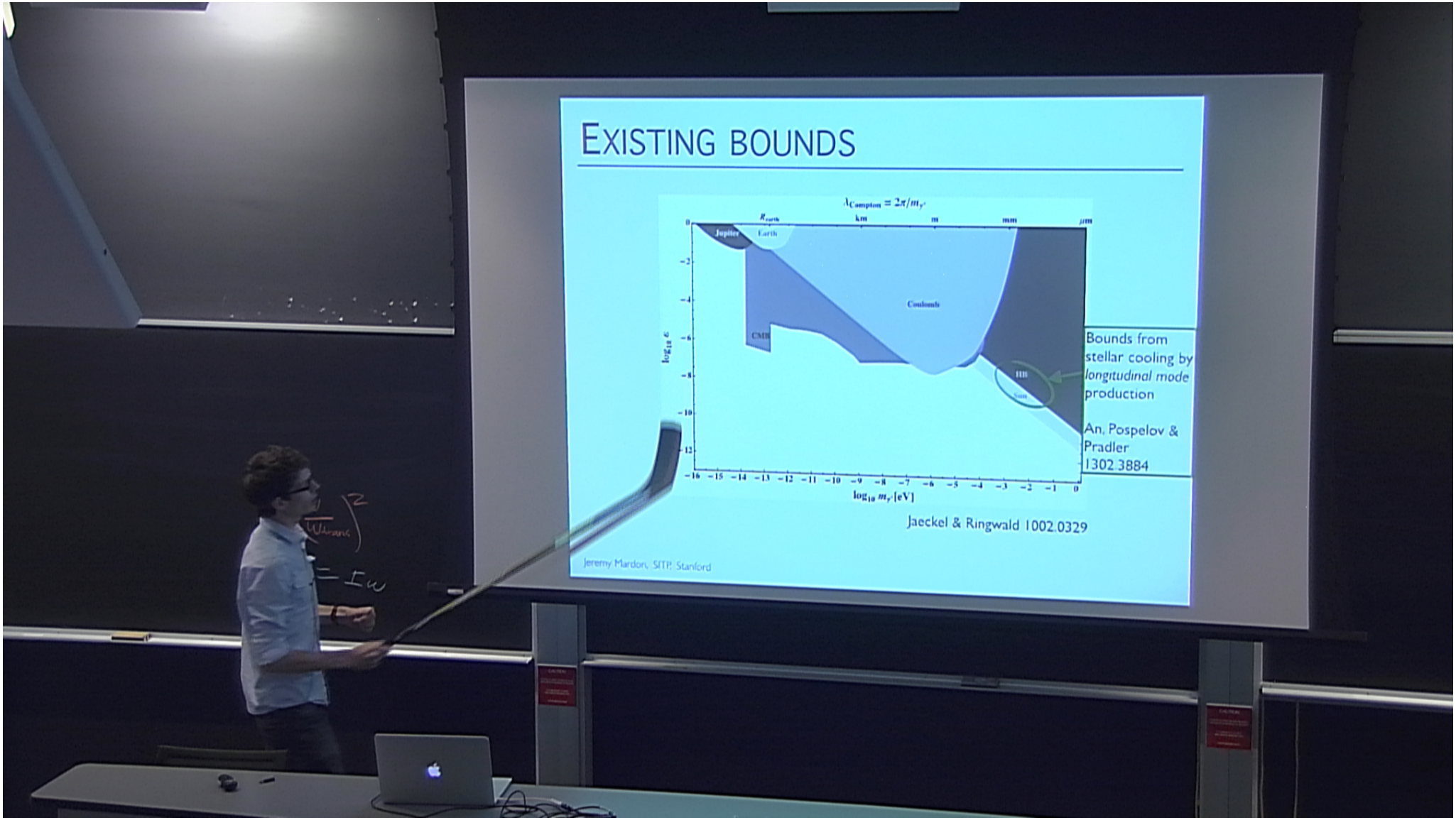
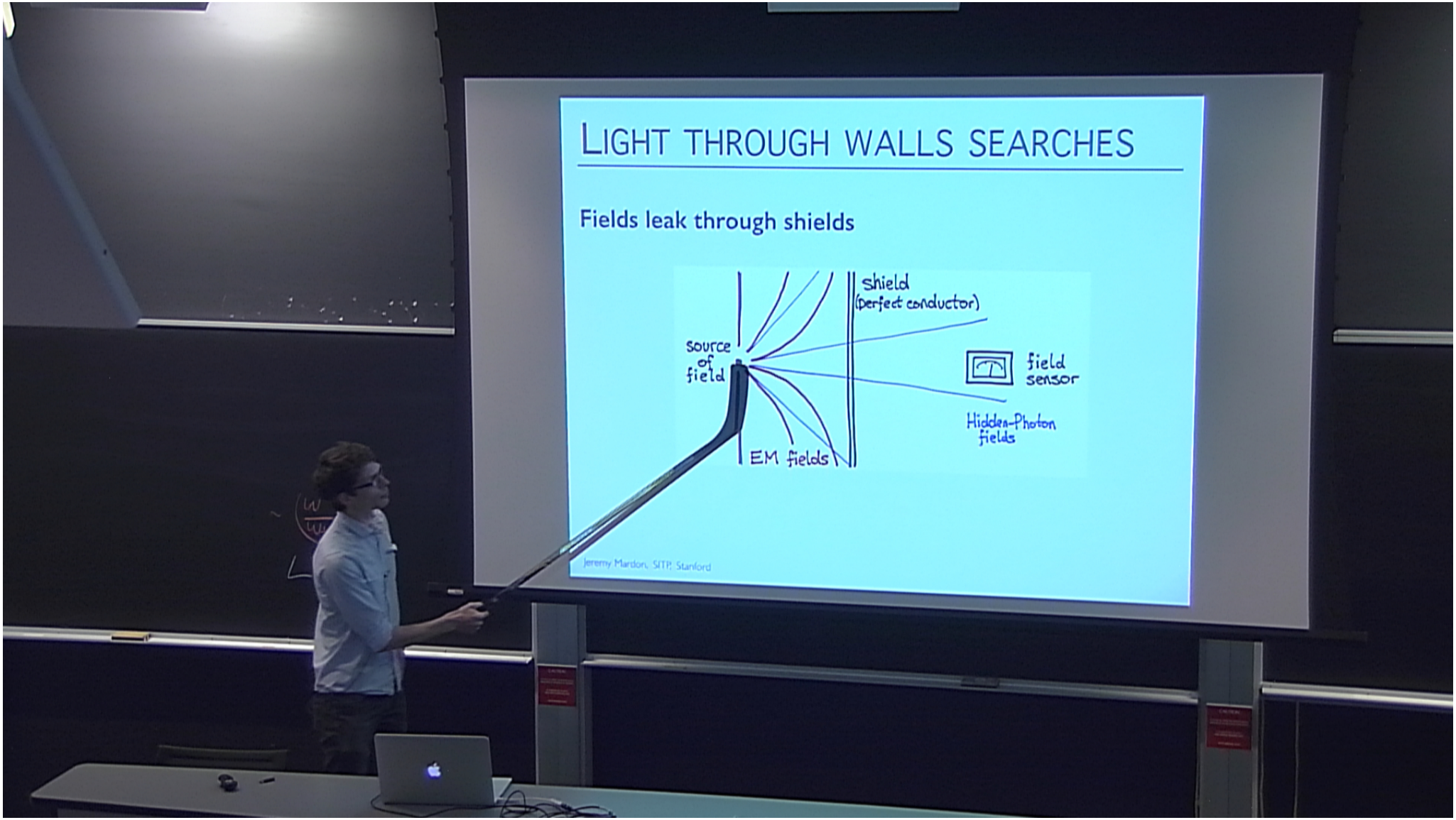
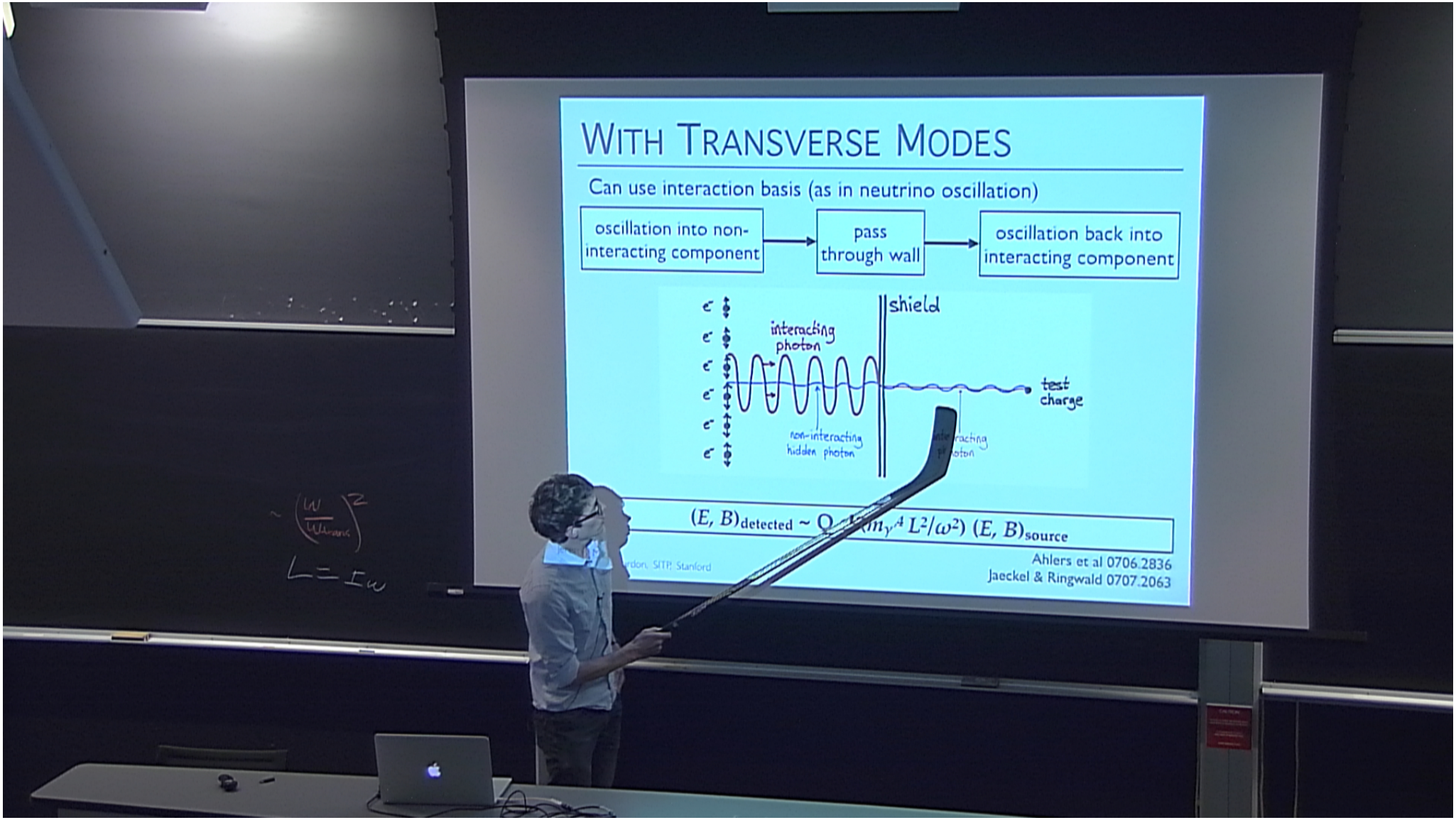
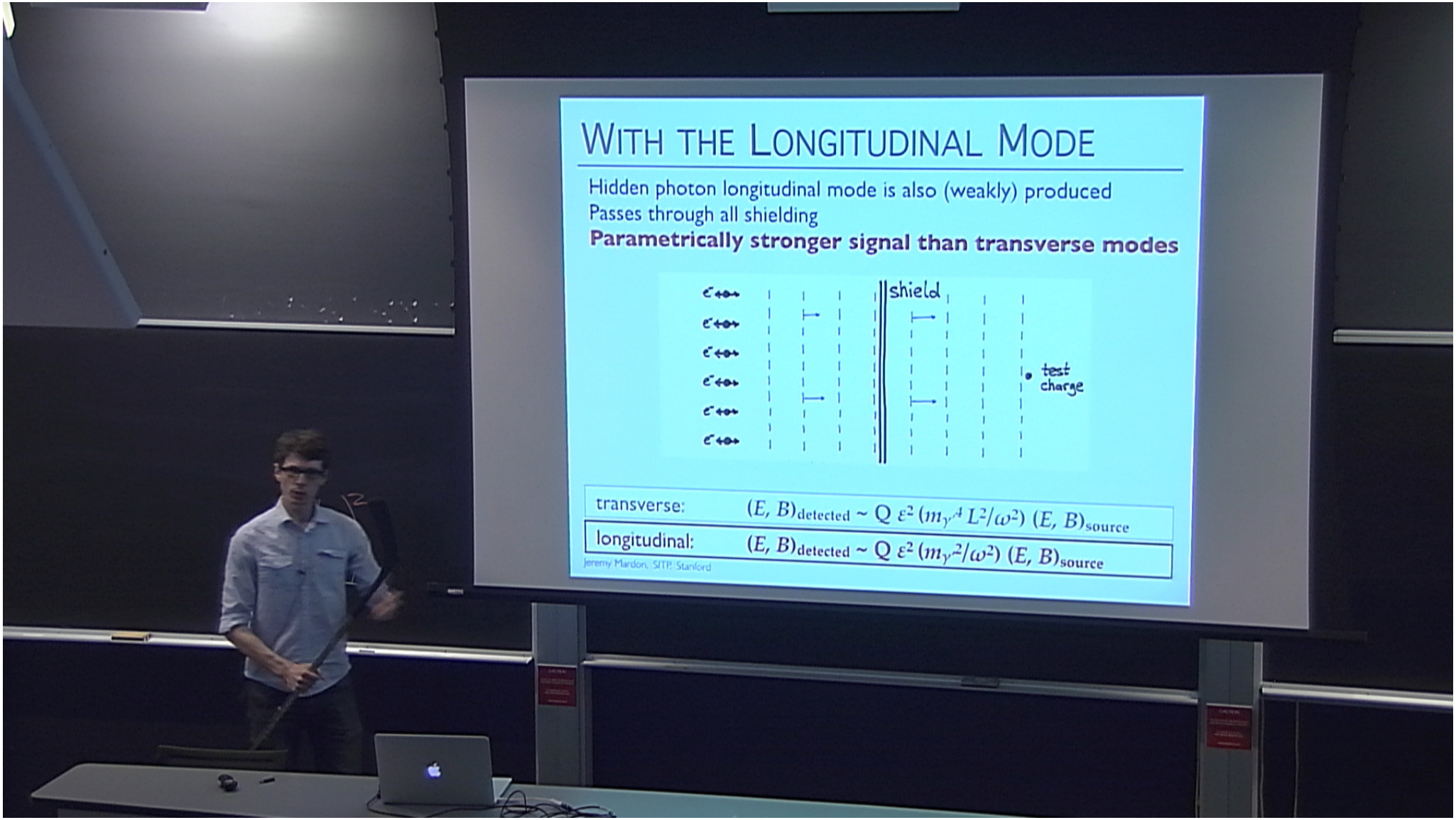
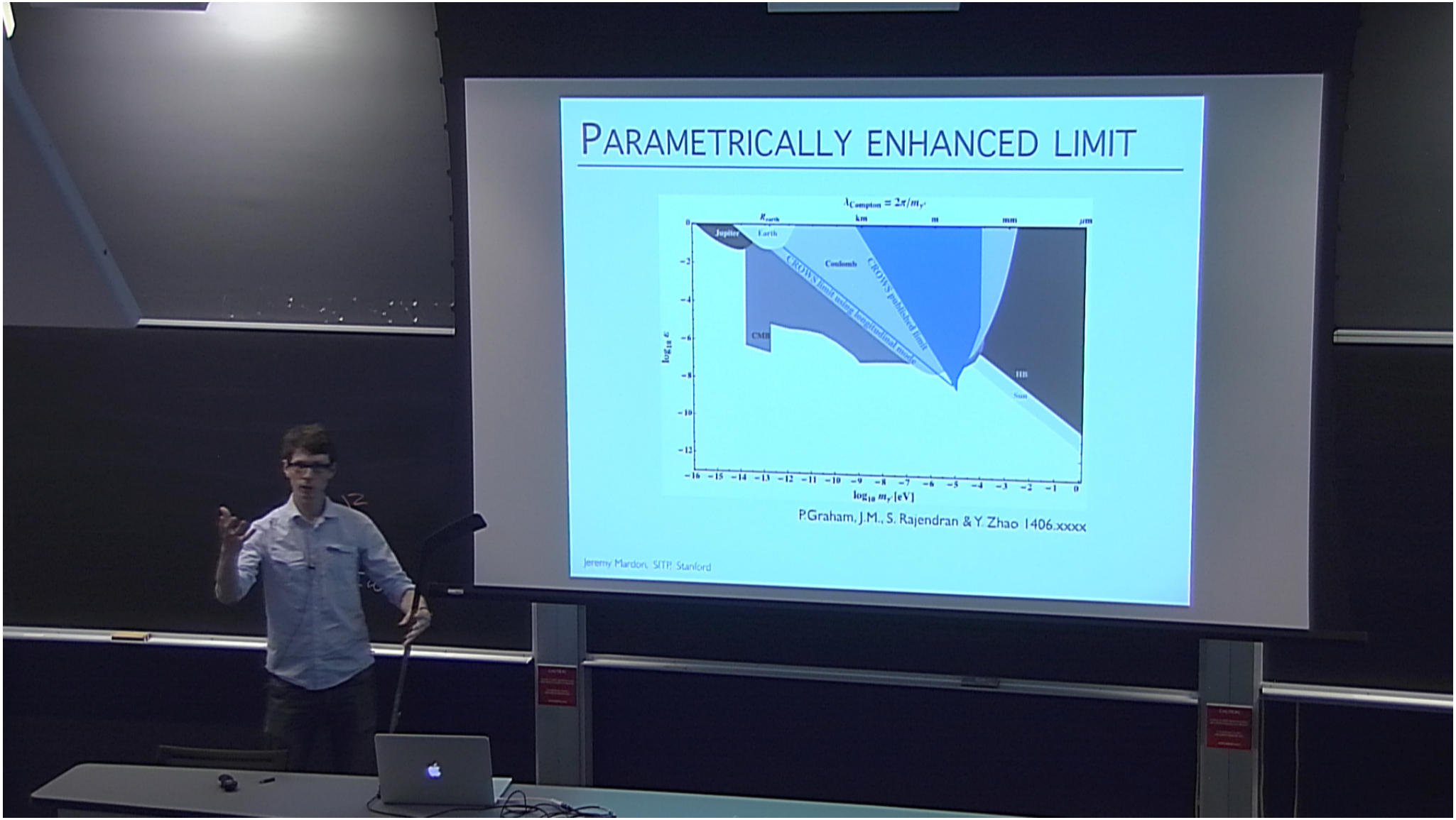
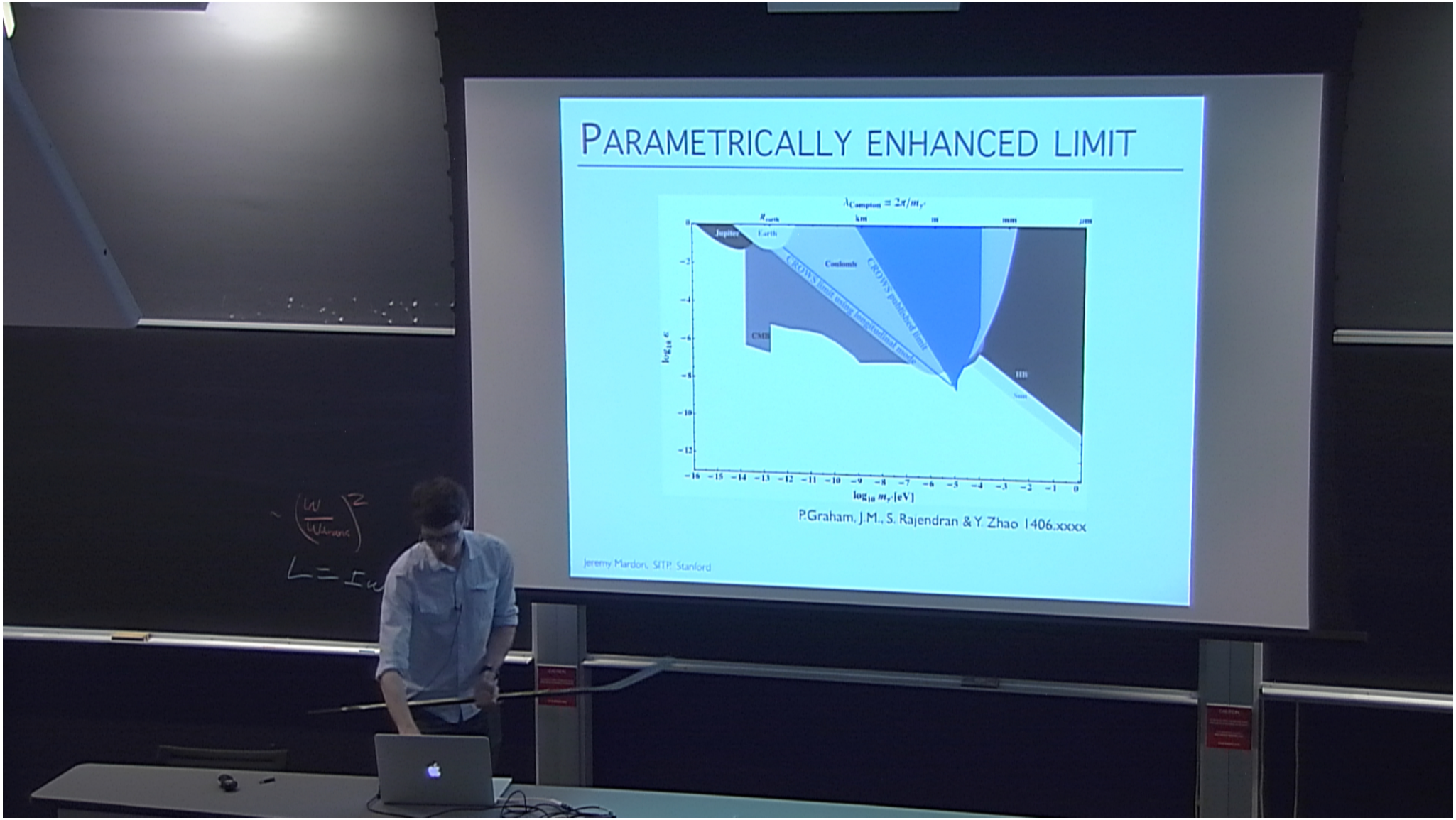

EXISTING BOUNDS
$\lambda_{Compton} = 2\pi/m_{\gamma'}$
R_{earth}
km
m
mm
μm
Jupiter
Earth
Coulomb
CMB
$\log_{10} \epsilon$
$\log_{10} m_{\gamma'}$ [eV]
Bounds from stellar cooling by *longitudinal mode* production
An, Pospelov & Pradler 1302.3884
Jaeckel & Ringwald 1002.0329
Jeremy Mardon, SITP, Stanford


LIGHT THROUGH WALLS SEARCHES
Fields leak through shields
shield
(perfect conductor)
source
of
field
field
sensor
Hidden-Photon
fields
EM fields
Jeremy Mardon, SITP, Stanford


WITH TRANSVERSE MODES
Can use interaction basis (as in neutrino oscillation)
oscillation into non-interacting component
pass through wall
oscillation back into interacting component
shield
interacting photon
test charge
non-interacting hidden photon
$(E, B)_{\text{detected}} \sim Q \cdot (m_{\gamma'}{}^4 L^2/\omega^2)\ (E, B)_{\text{source}}$
Ahlers et al 0706.2836
Jaeckel & Ringwald 0707.2063


WITH THE LONGITUDINAL MODE
Hidden photon longitudinal mode is also (weakly) produced
Passes through all shielding
Parametrically stronger signal than transverse modes
shield
test charge
transverse: $(E, B)_{\text{detected}} \sim Q\, \varepsilon^2\, (m_{\gamma'}{}^4 L^2/\omega^2)\, (E, B)_{\text{source}}$
longitudinal: $(E, B)_{\text{detected}} \sim Q\, \varepsilon^2\, (m_{\gamma'}{}^2/\omega^2)\, (E, B)_{\text{source}}$
Jeremy Mardon, SITP, Stanford


PARAMETRICALLY ENHANCED LIMIT
$\lambda_{Compton} = 2\pi/m_{\gamma'}$
R_{earth}
km
m
mm
μm
Jupiter
Earth
Coulomb
CROWS published limit
CROWS limit using longitudinal mode
CMB
HB
Sun
$\log_{10} \epsilon$
$\log_{10} m_{\gamma'}$ [eV]
P.Graham, J.M., S. Rajendran & Y. Zhao 1406.xxxx
Jeremy Mardon, SITP, Stanford


PARAMETRICALLY ENHANCED LIMIT
$\lambda_{Compton} = 2\pi/m_{\gamma'}$
R_{earth}
km
m
mm
μm
Jupiter
Earth
Coulomb
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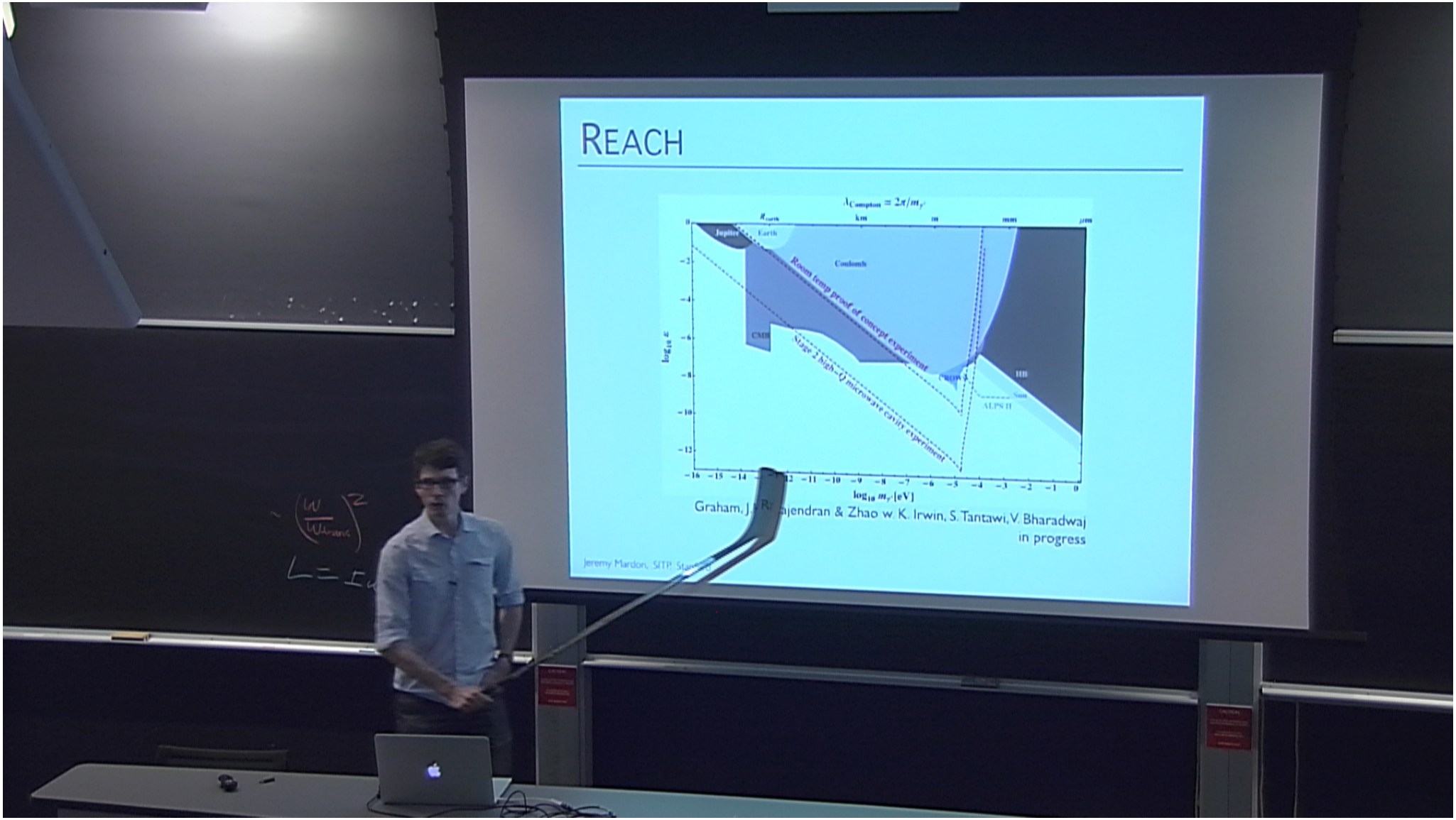
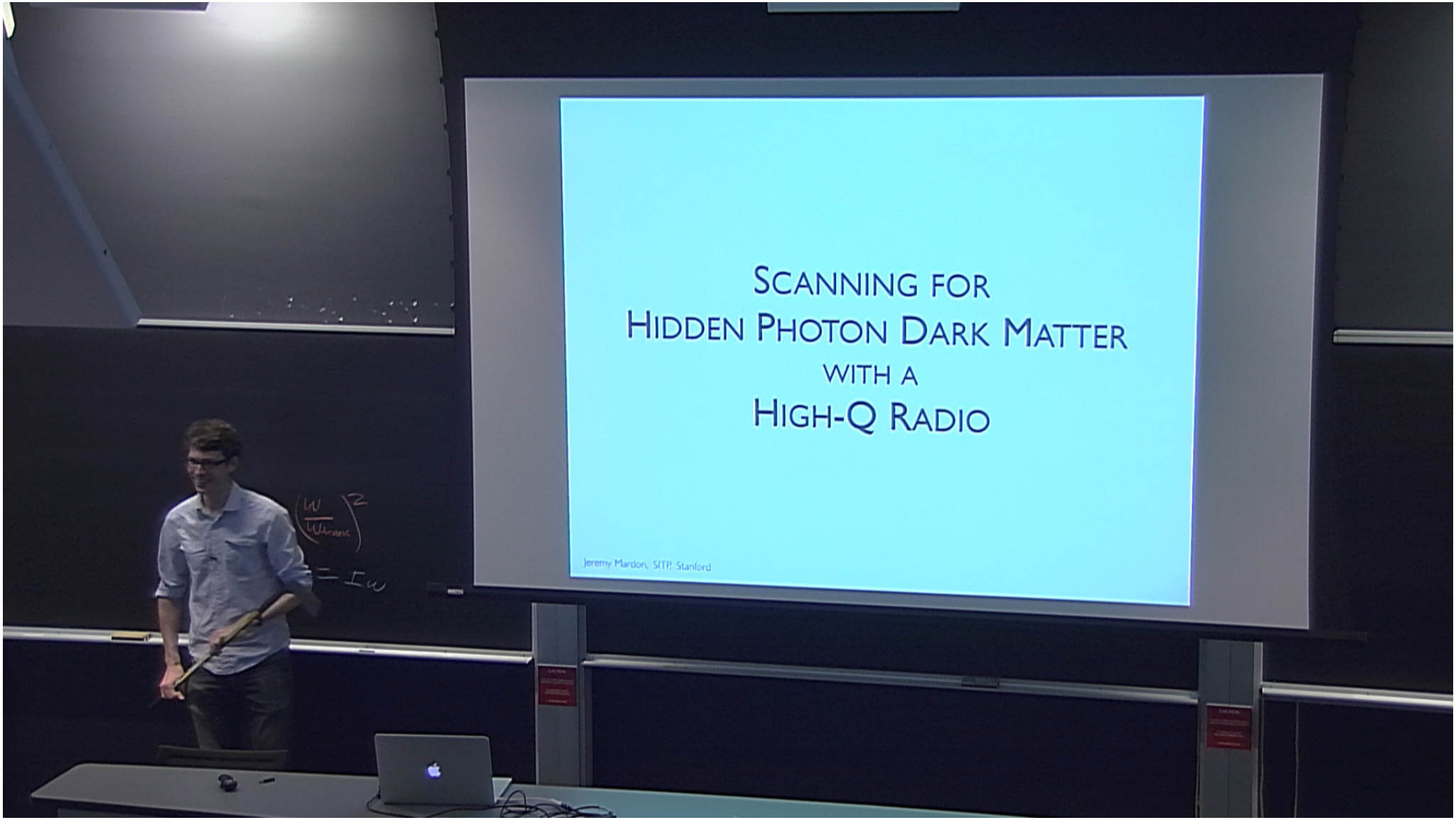
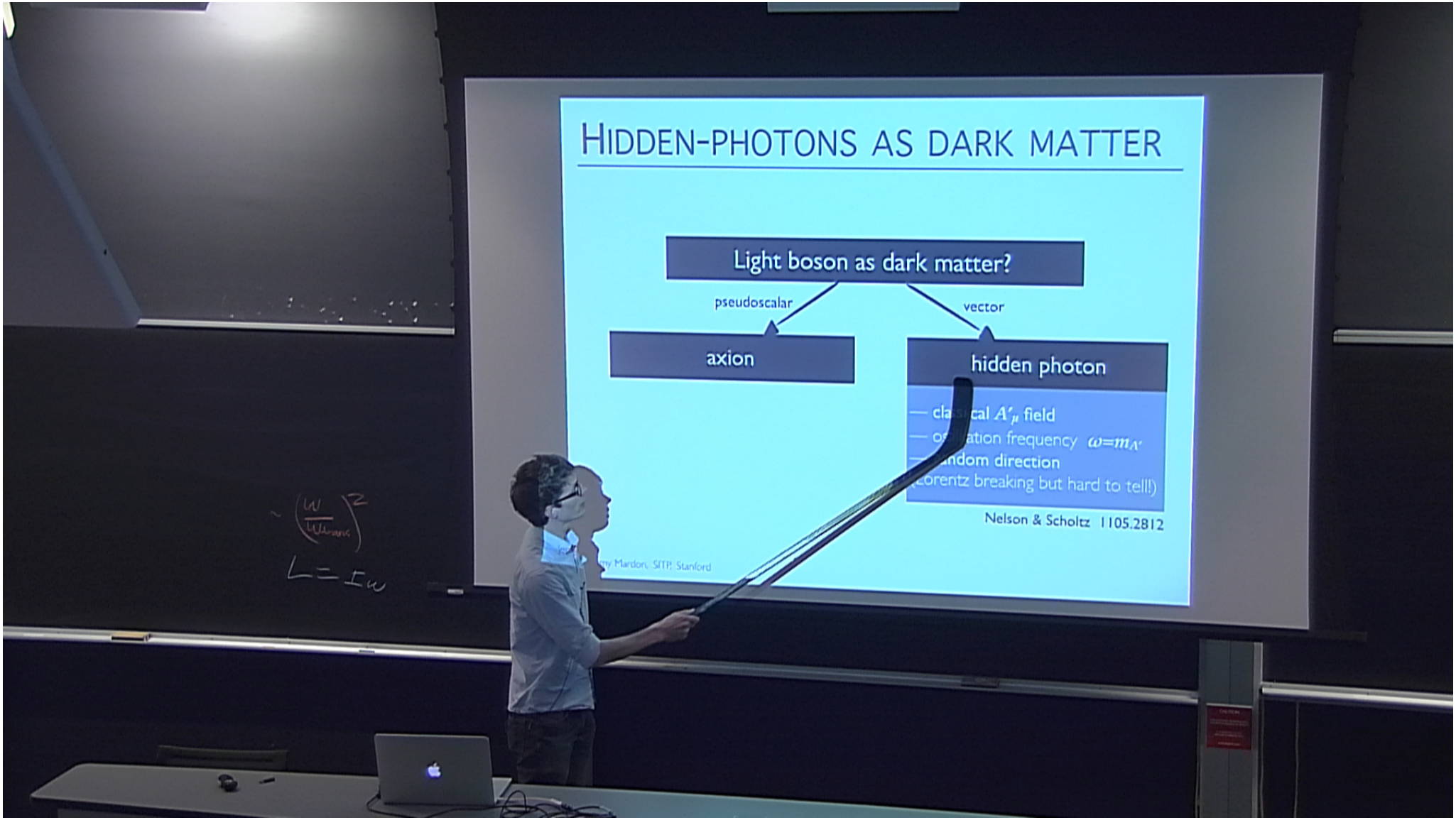
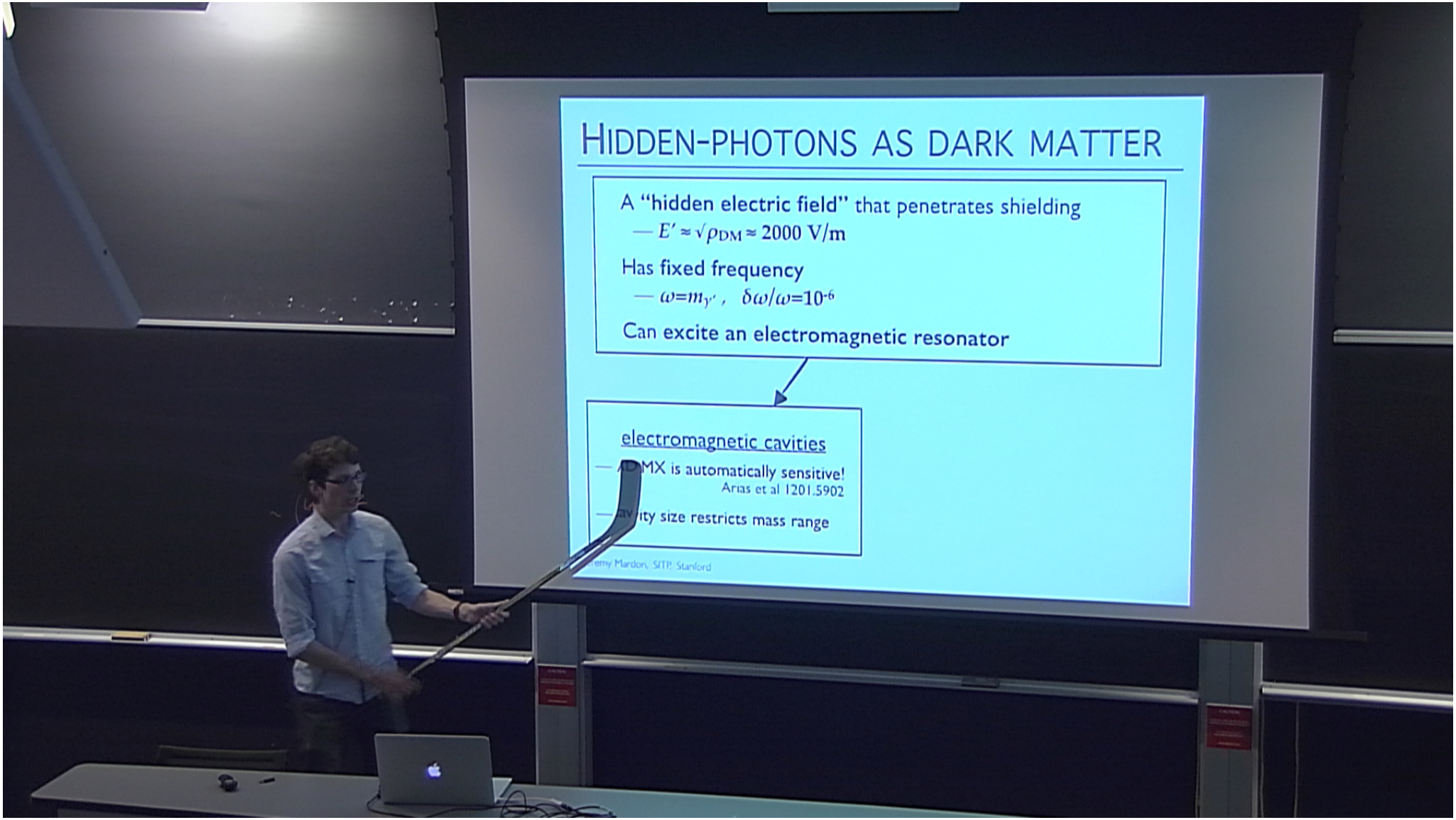
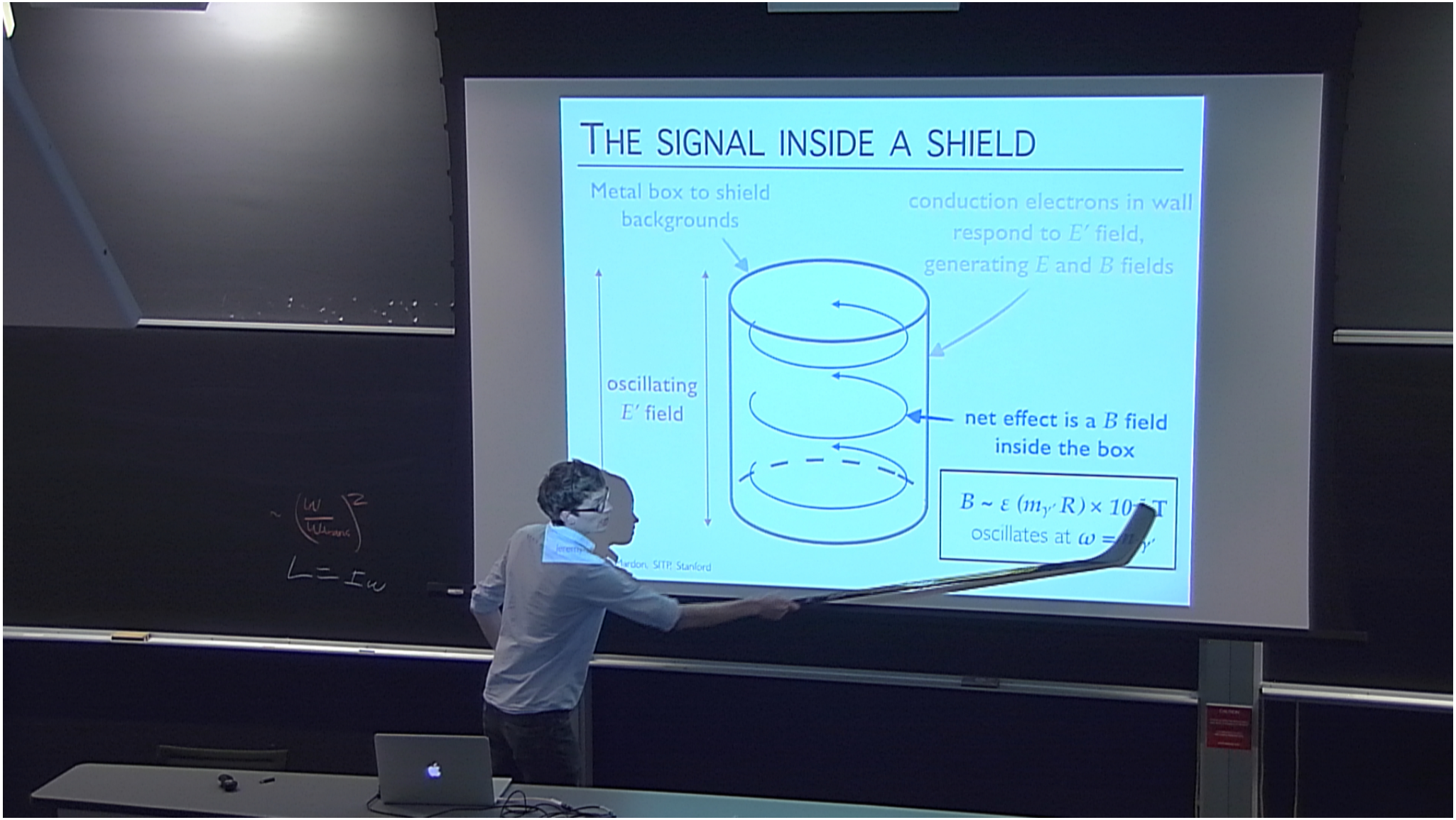
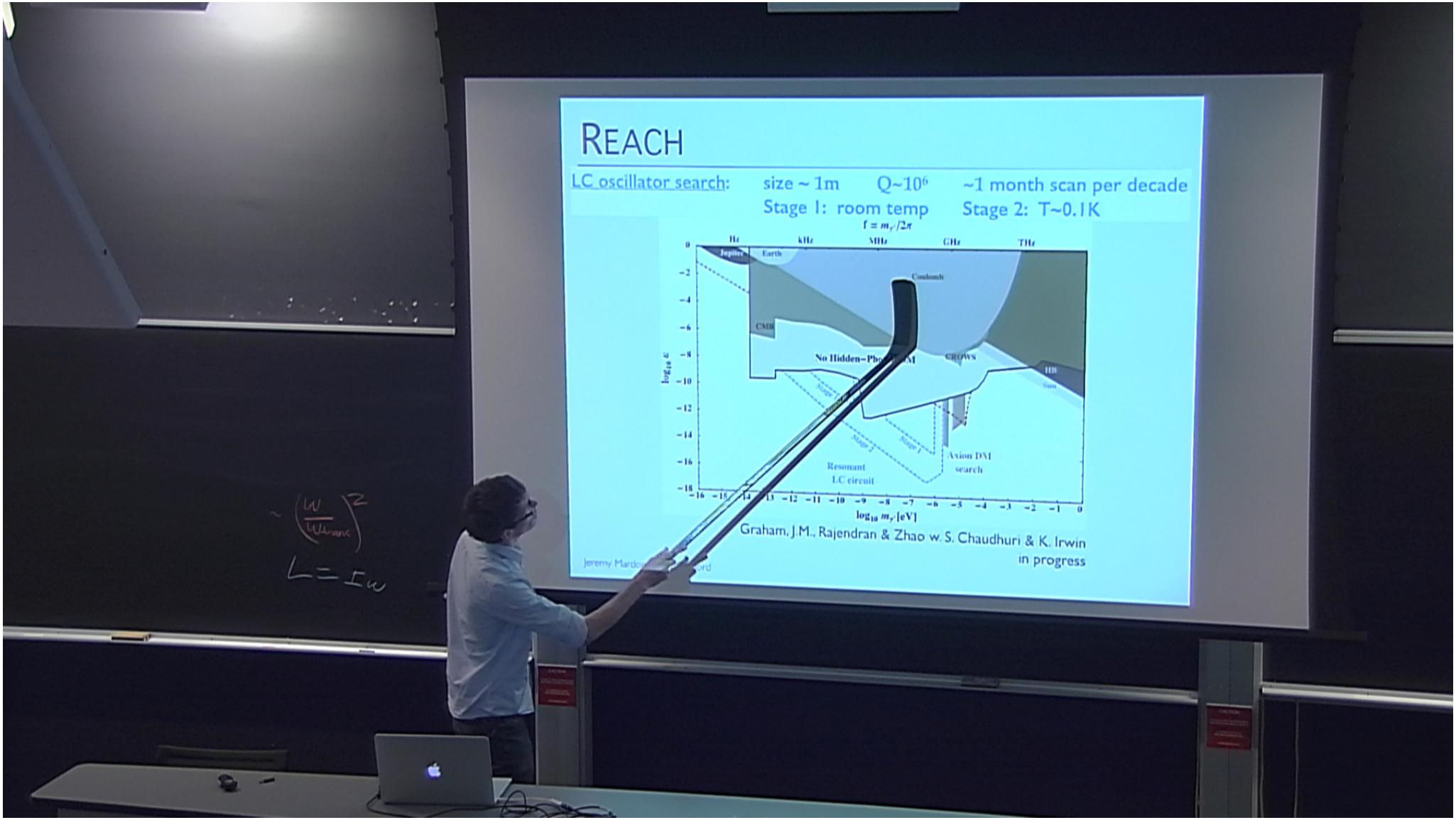

REACH
$\lambda_{\rm Compton} = 2\pi/m_{\gamma'}$
km
m
mm
μm
Jupiter
Earth
Coulomb
Room temp proof of concept experiment
CMB
Size 2 high-Q microwave cavity experiment
ALPS II
$\log_{10}\varepsilon$
$\log_{10} m_{\gamma'}$ [eV]
Graham, J. R. Rajendran & Zhao w/ K. Irwin, S. Tantawi, V. Bharadwaj
in progress
Jeremy Mardon, SITP, Stanford

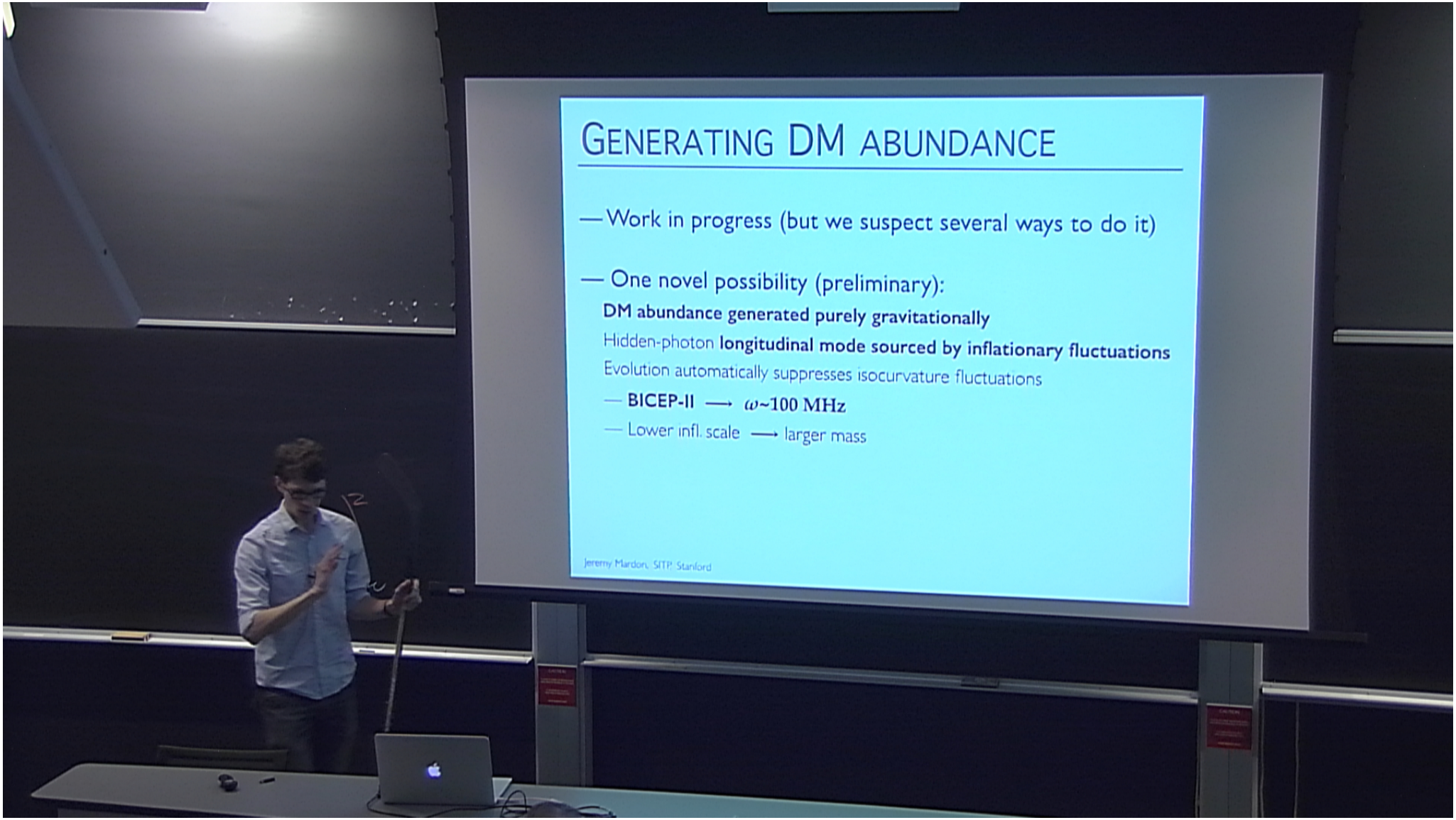

SCANNING FOR
HIDDEN PHOTON DARK MATTER
WITH A
HIGH-Q RADIO
Jeremy Mardon, SITP, Stanford


HIDDEN-PHOTONS AS DARK MATTER
Light boson as dark matter?
pseudoscalar
vector
axion
hidden photon
Nelson & Scholtz 1105.2812


HIDDEN-PHOTONS AS DARK MATTER
A "hidden electric field" that penetrates shielding
— $E' \approx \sqrt{\rho_{DM}} \approx 2000$ V/m
Has fixed frequency
— $\omega = m_{\gamma'}$, $\delta\omega/\omega = 10^{-6}$
Can excite an electromagnetic resonator
electromagnetic cavities
— ADMX is automatically sensitive!
Arias et al 1201.5902
— cavity size restricts mass range


THE SIGNAL INSIDE A SHIELD
Metal box to shield backgrounds
conduction electrons in wall respond to E' field, generating E and B fields
oscillating E' field
net effect is a B field inside the box
$B \sim \varepsilon\,(m_{\gamma'} R) \times 10^{-}$ T
oscillates at $\omega = m_{\gamma'}$


REACH
LC oscillator search: size ~ 1m Q~10^6 ~1 month scan per decade
Stage 1: room temp Stage 2: T~0.1K
f = m_γ/2π
Hz
kHz
MHz
GHz
THz
Jupiter
Earth
Coulomb
CMB
No Hidden-Photon DM
CROWS
HB
Sun
Stage 1
Stage 2
Stage 3
Resonant
LC circuit
Axion DM
search
log10 ε
log10 m_γ [eV]
Graham, J.M., Rajendran & Zhao w. S. Chaudhuri & K. Irwin
in progress
Jeremy Mardon
Stanford


GENERATING DM ABUNDANCE
— Work in progress (but we suspect several ways to do it)
— One novel possibility (preliminary):
DM abundance generated purely gravitationally
Hidden-photon longitudinal mode sourced by inflationary fluctuations
Evolution automatically suppresses isocurvature fluctuations
— BICEP-II ⟶ ω~100 MHz
— Lower infl. scale ⟶ larger mass
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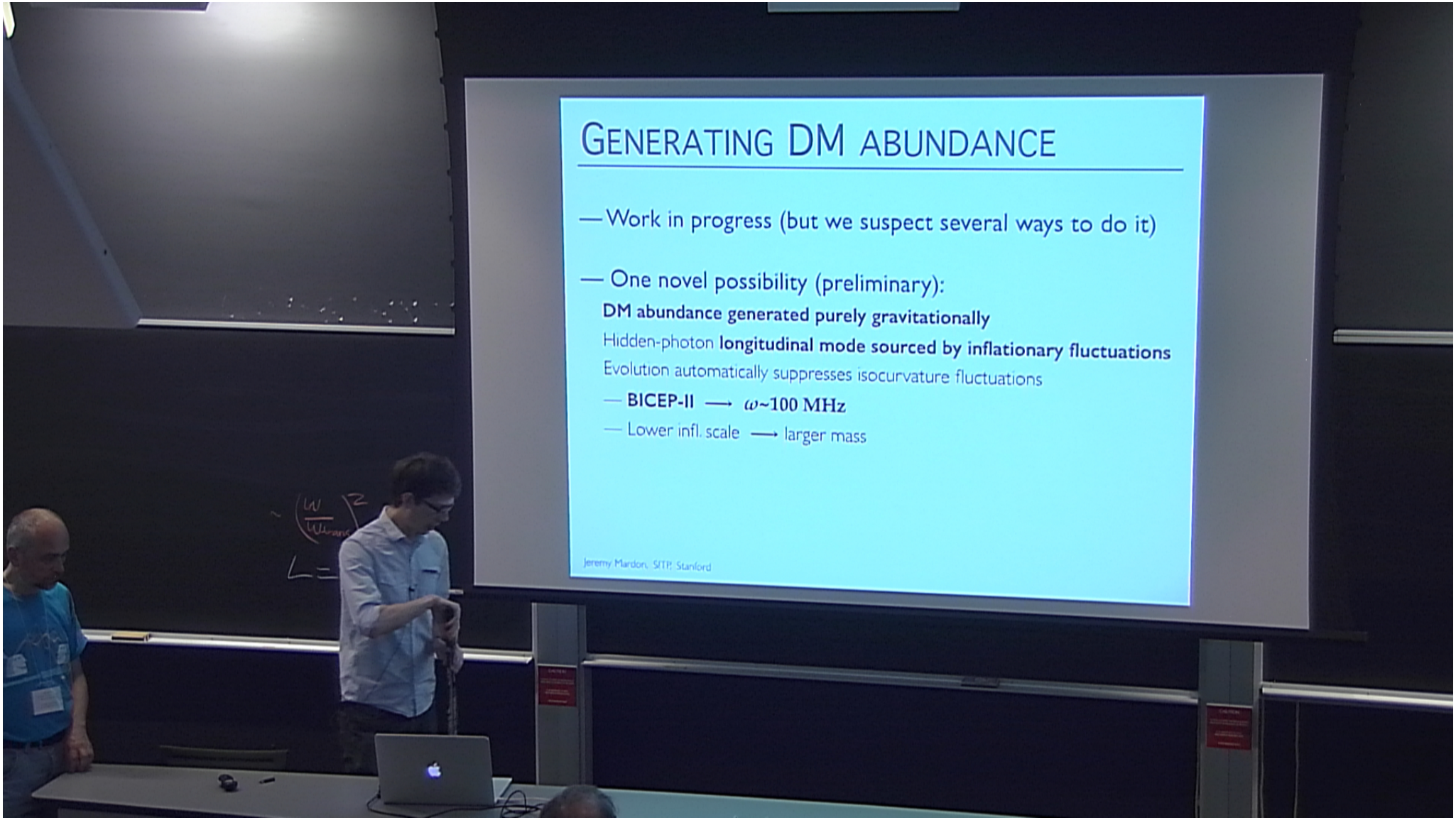
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