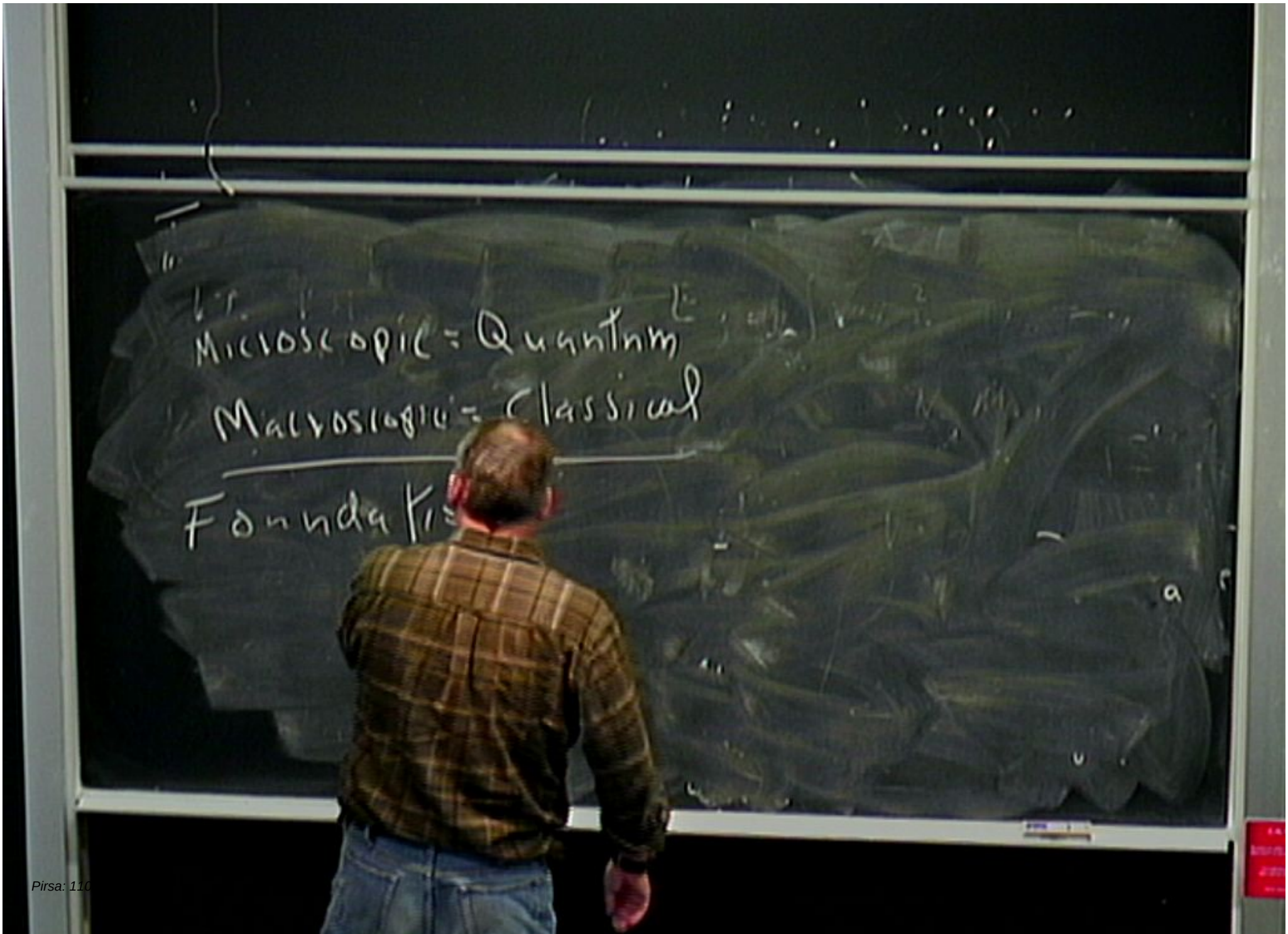
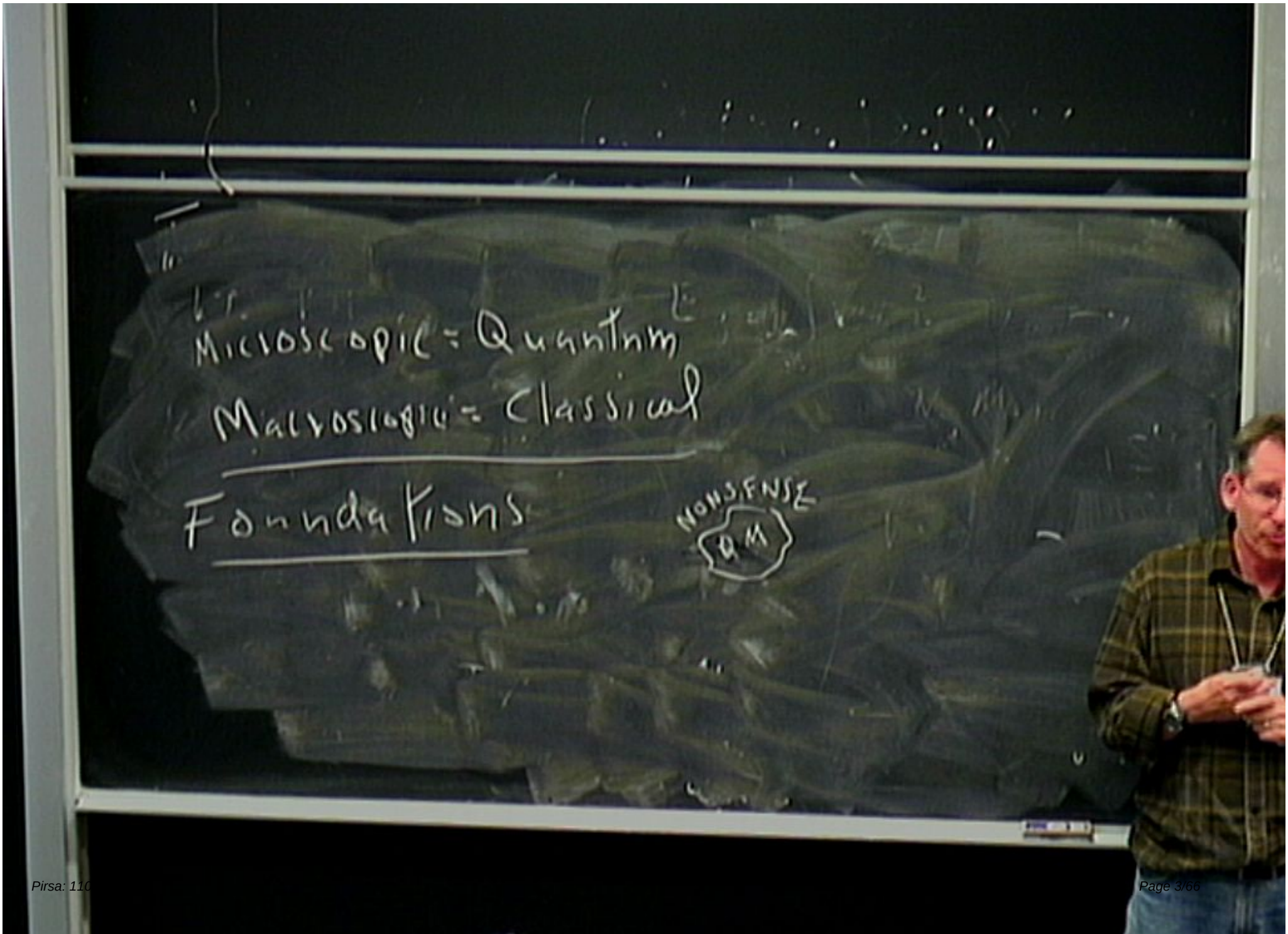
Title: Simulating the universe with a quantum computer

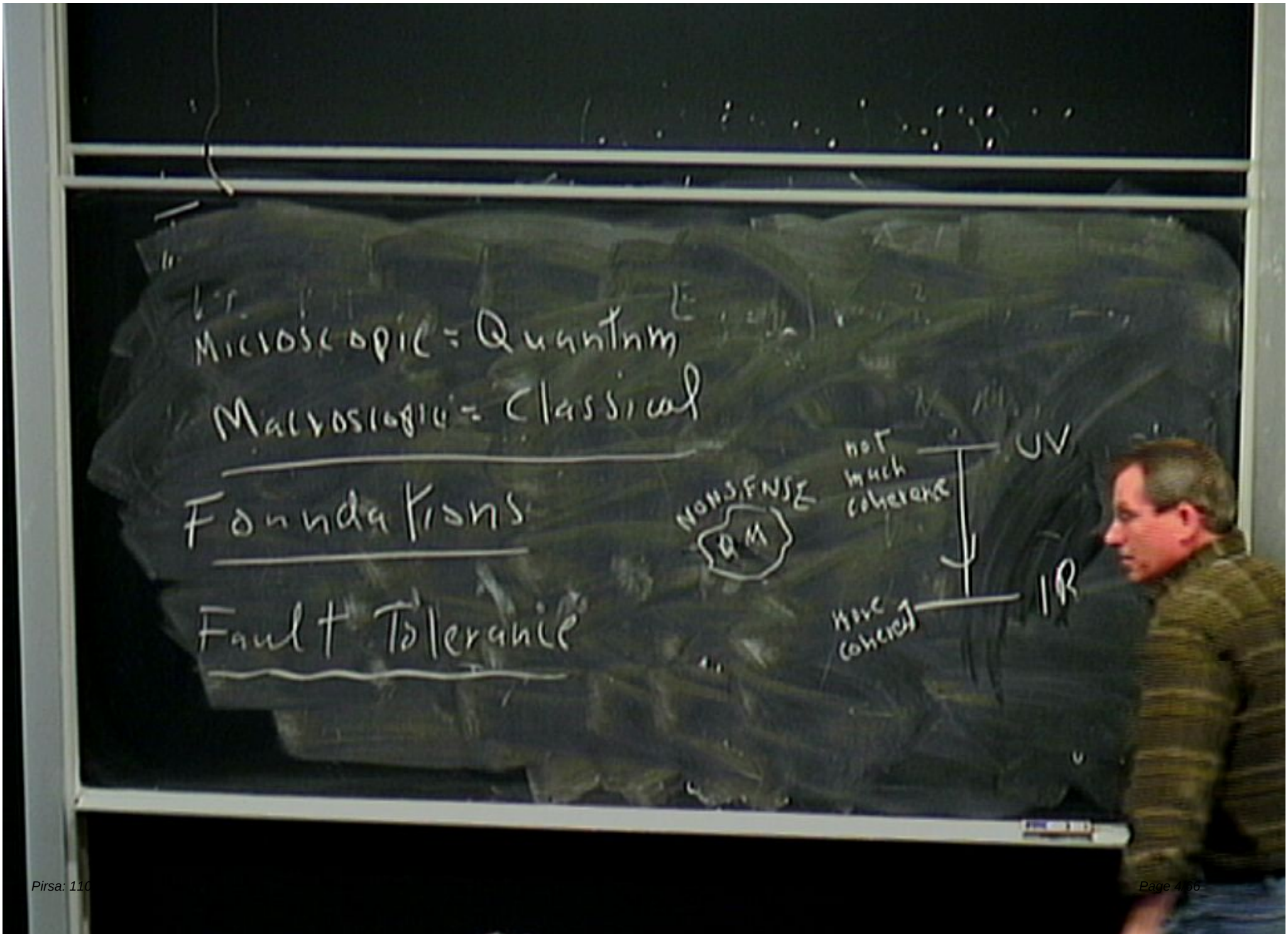
Date: Jun 22, 2011 04:25 PM

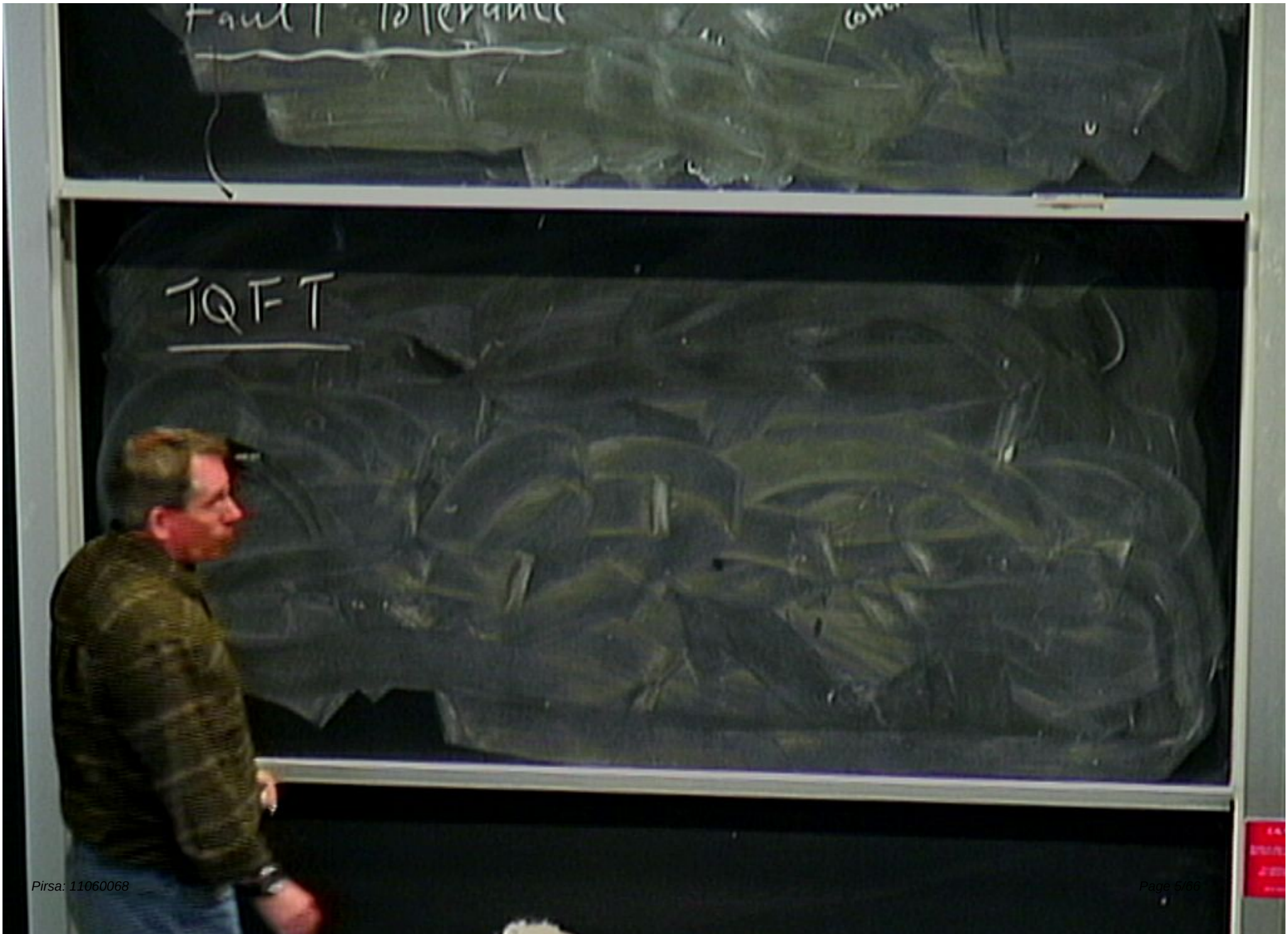
URL: http://pirsa.org/11060068

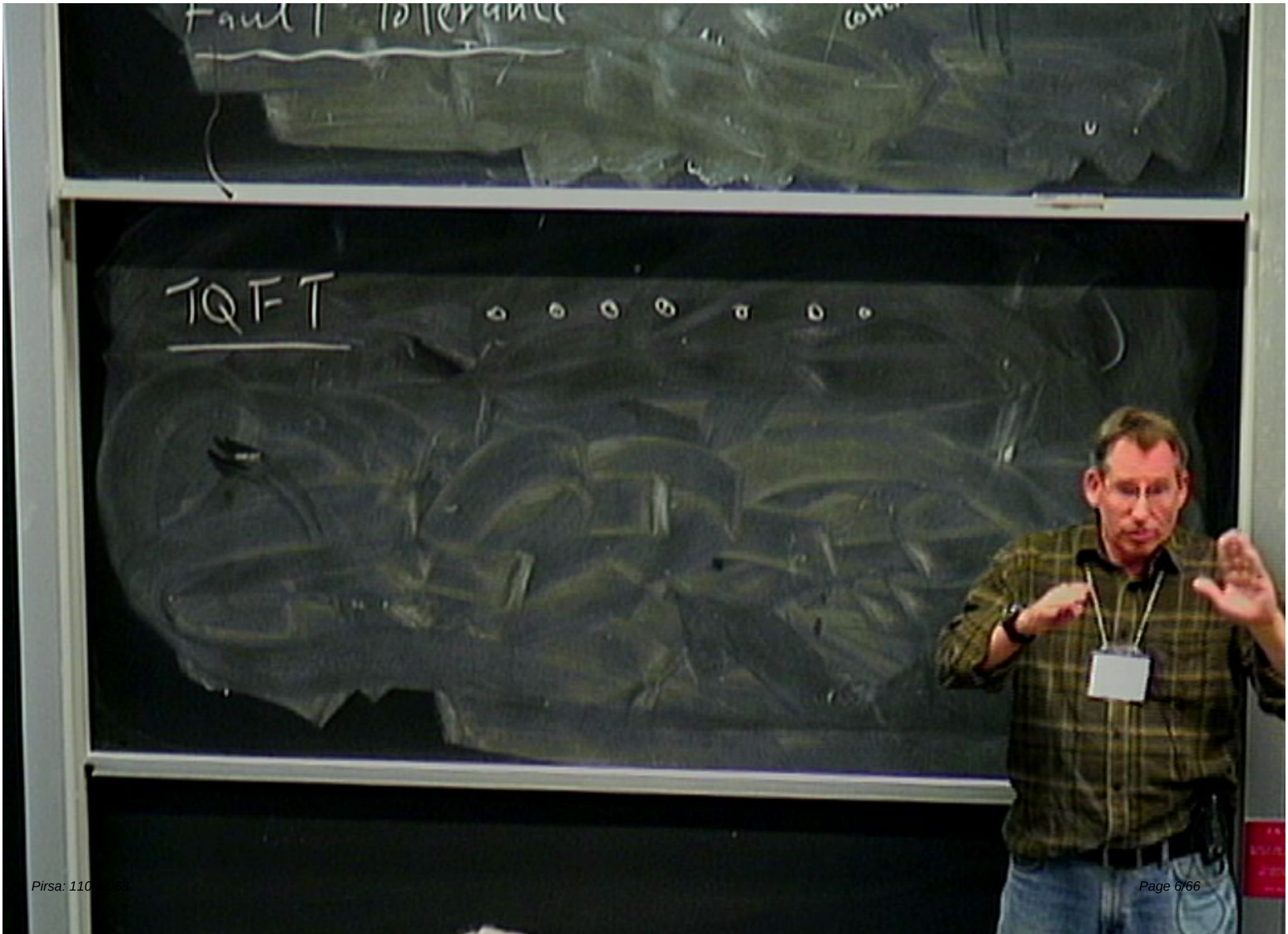
Abstract: I'll discuss some recent insights regarding the complexity of simulating highly entangled quantum systems using classical and quantum computers, and what these advances might imply about the quantum state of the early universe.


Microscopic = Quantum
Macroscopic = Classical


Microscopic = Quantum
Macroscopic = Classical
Foundations
NONSENSE
QM


Microscopic = Quantum
Macroscopic = Classical
Foundations
Fault Tolerance
NONSENSE
QM
not much coherence
UV
IR
have coherent


TQFT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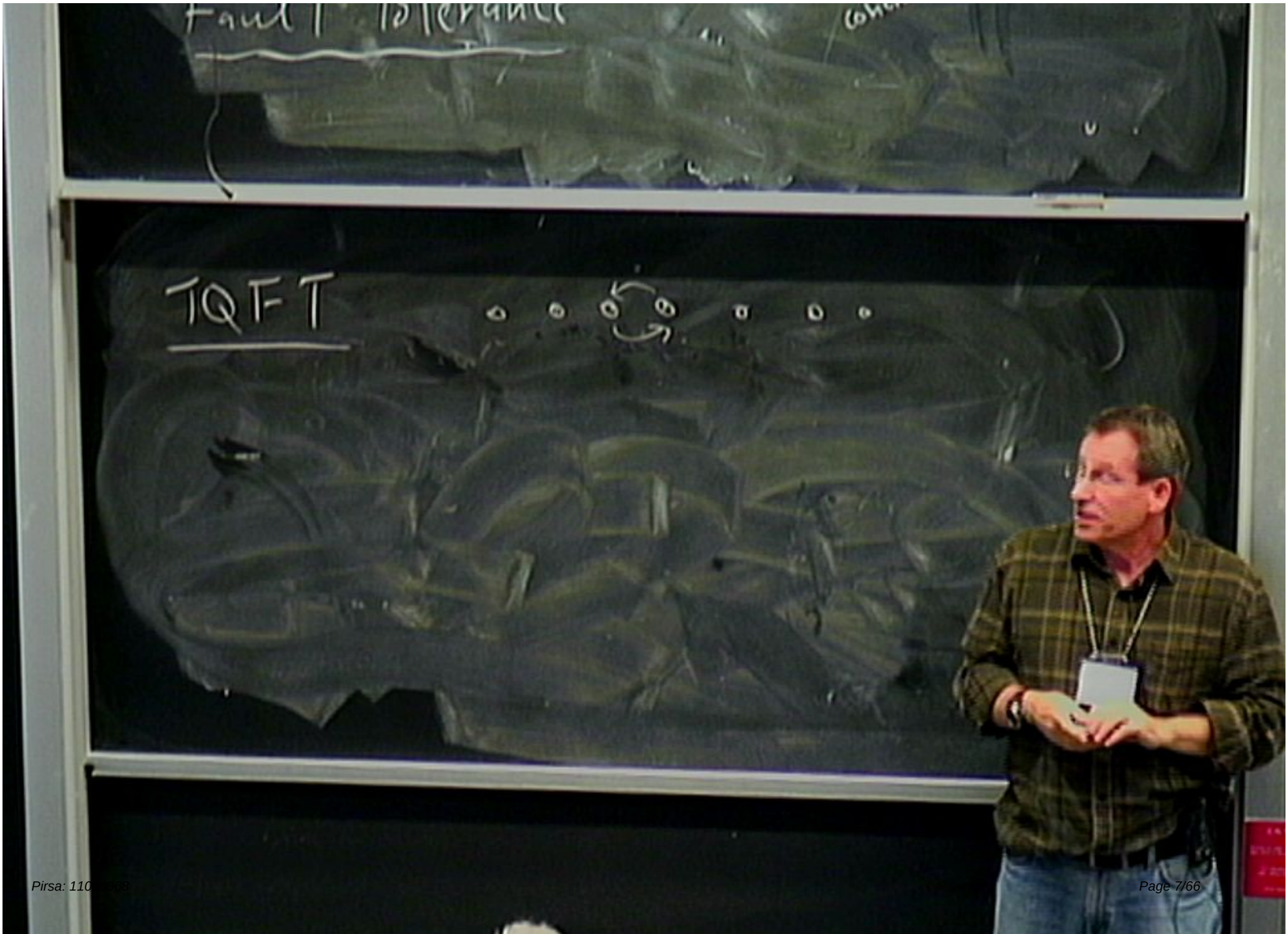
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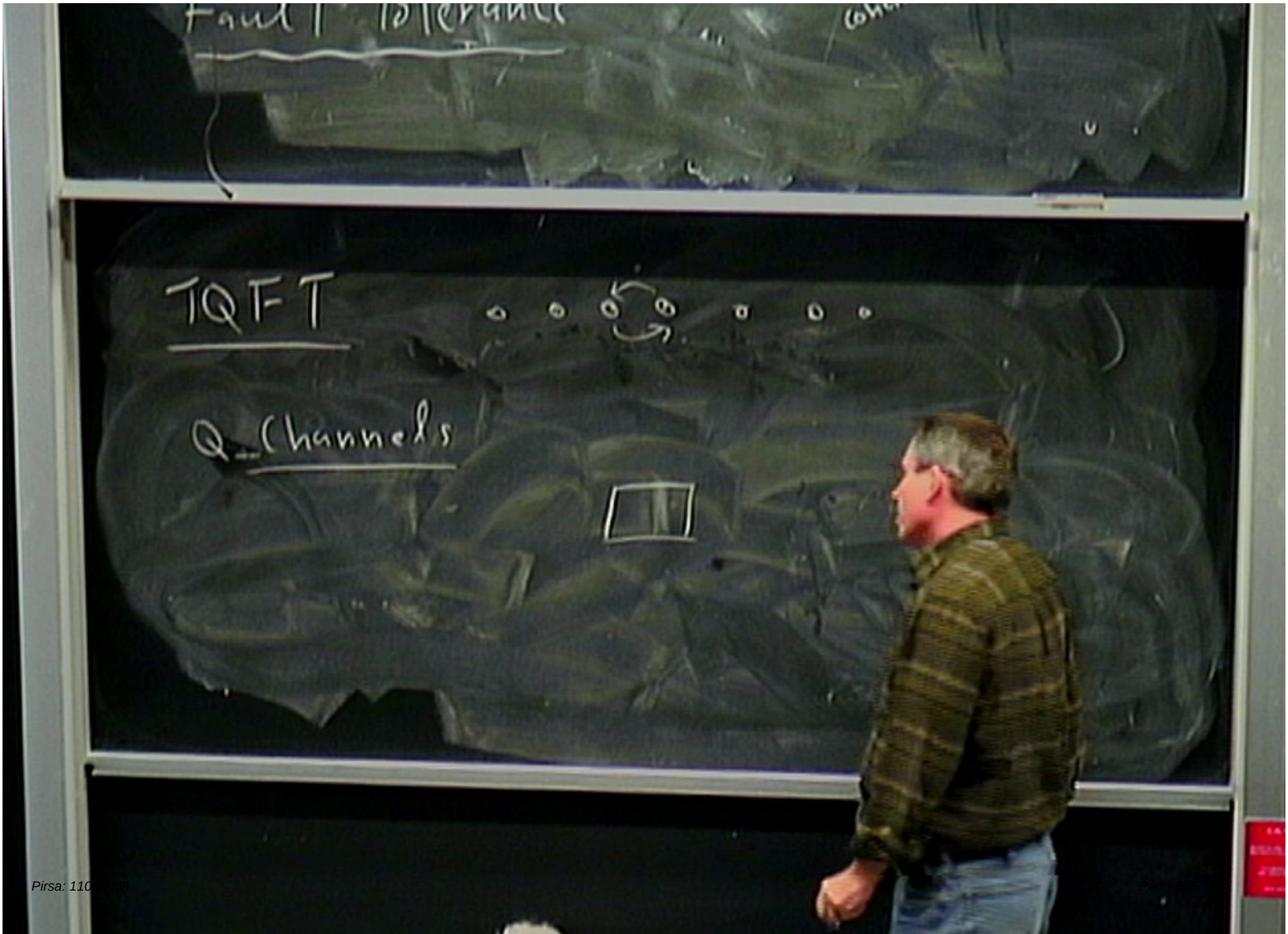
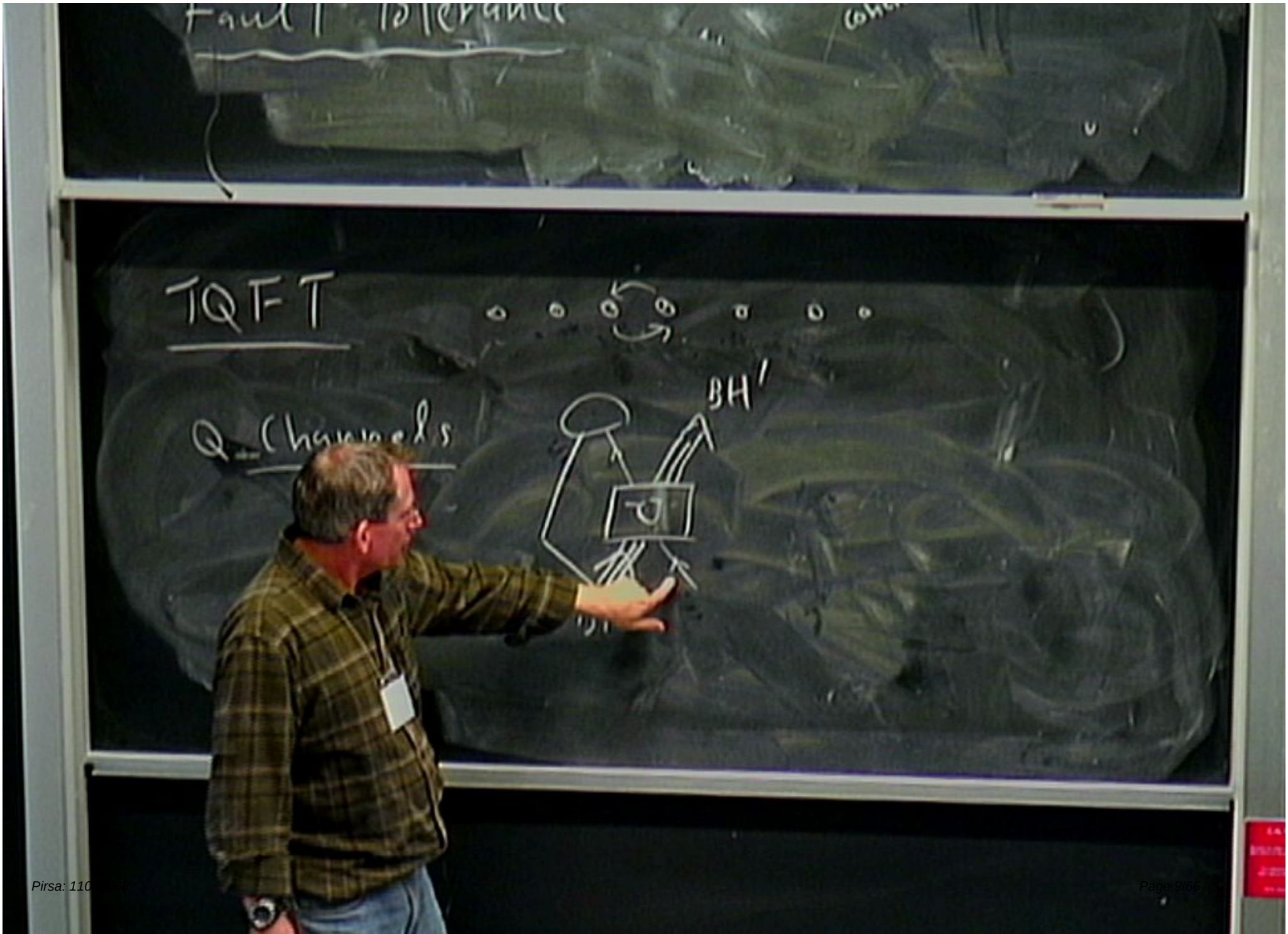
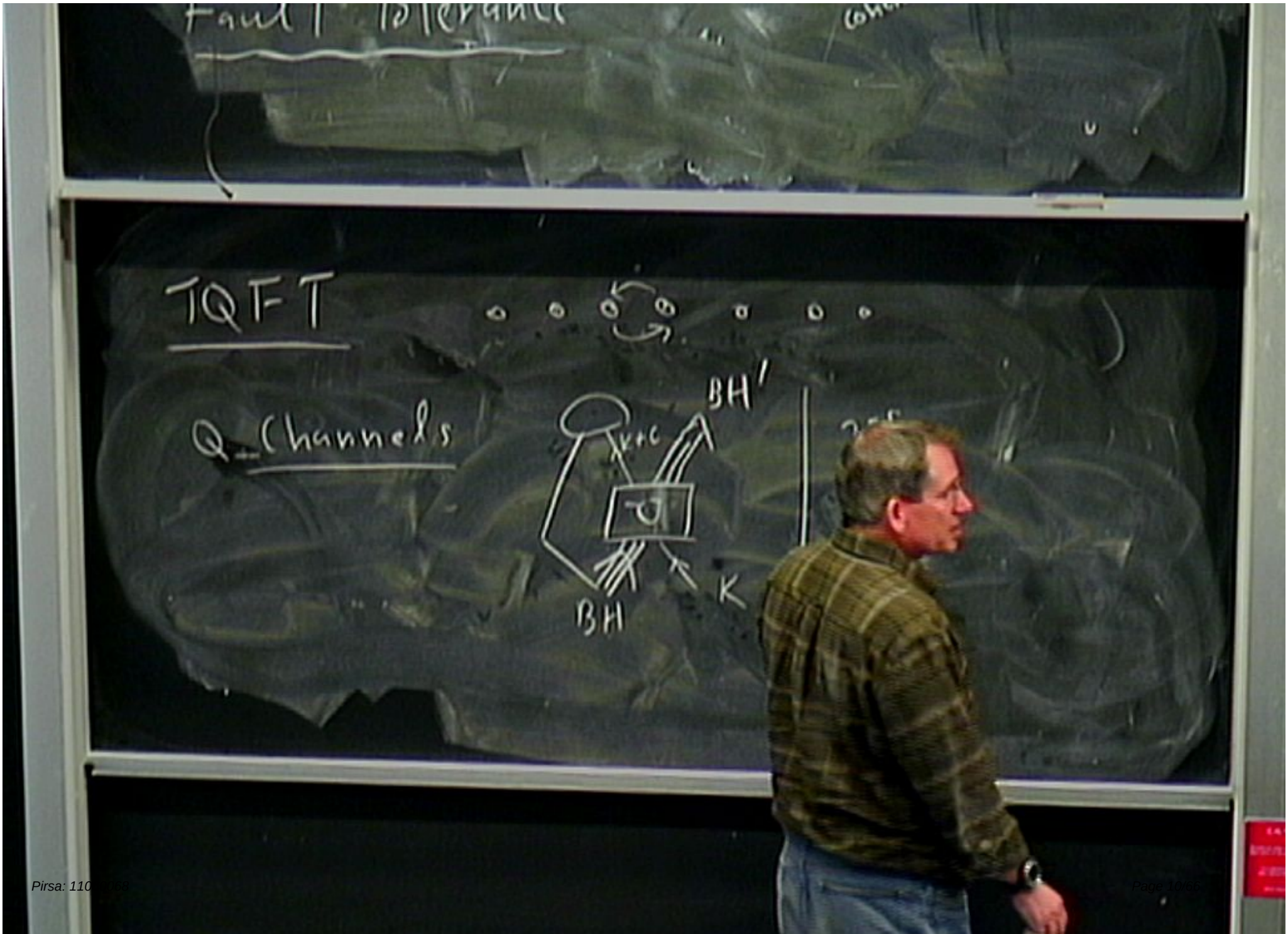
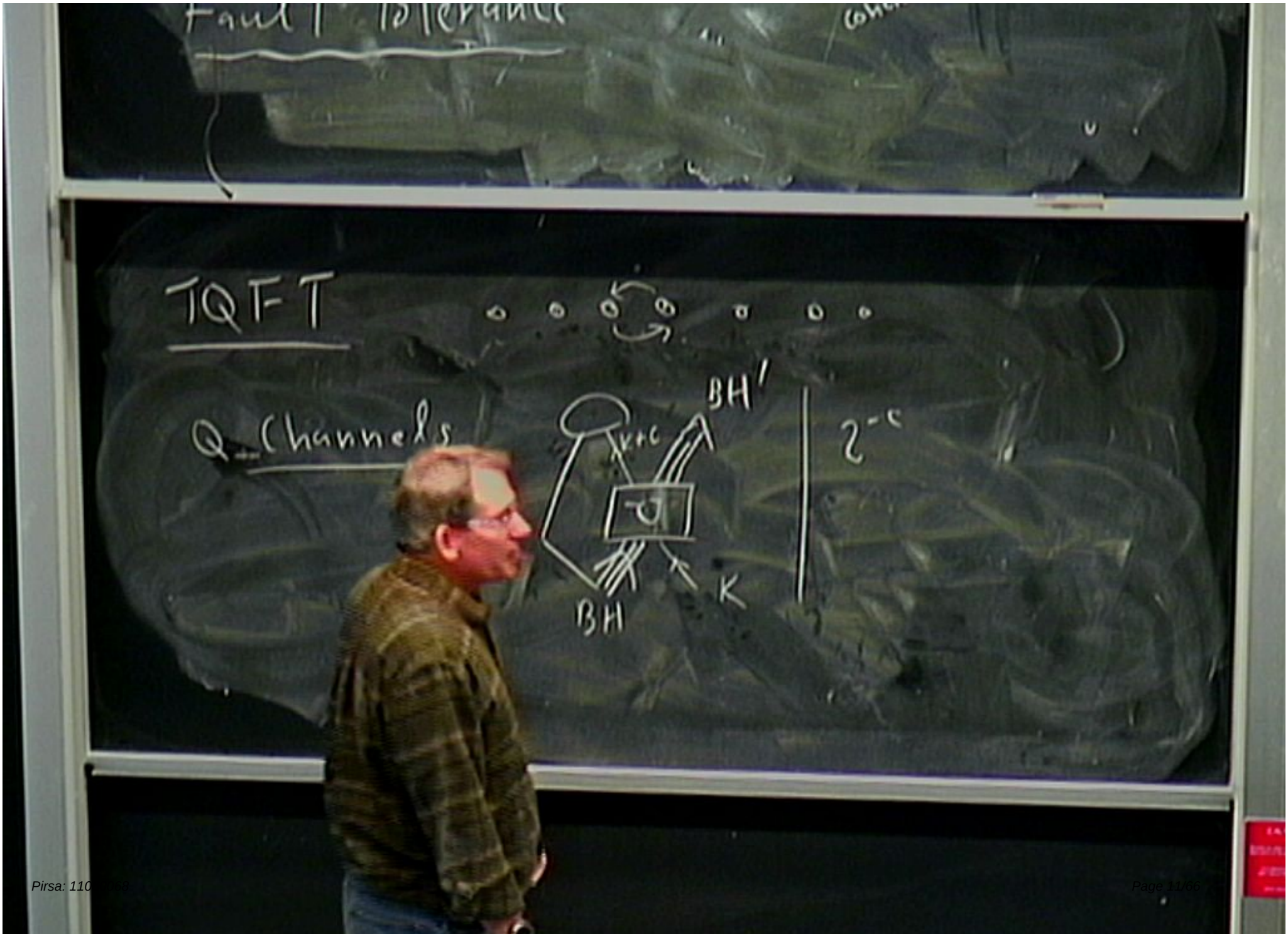
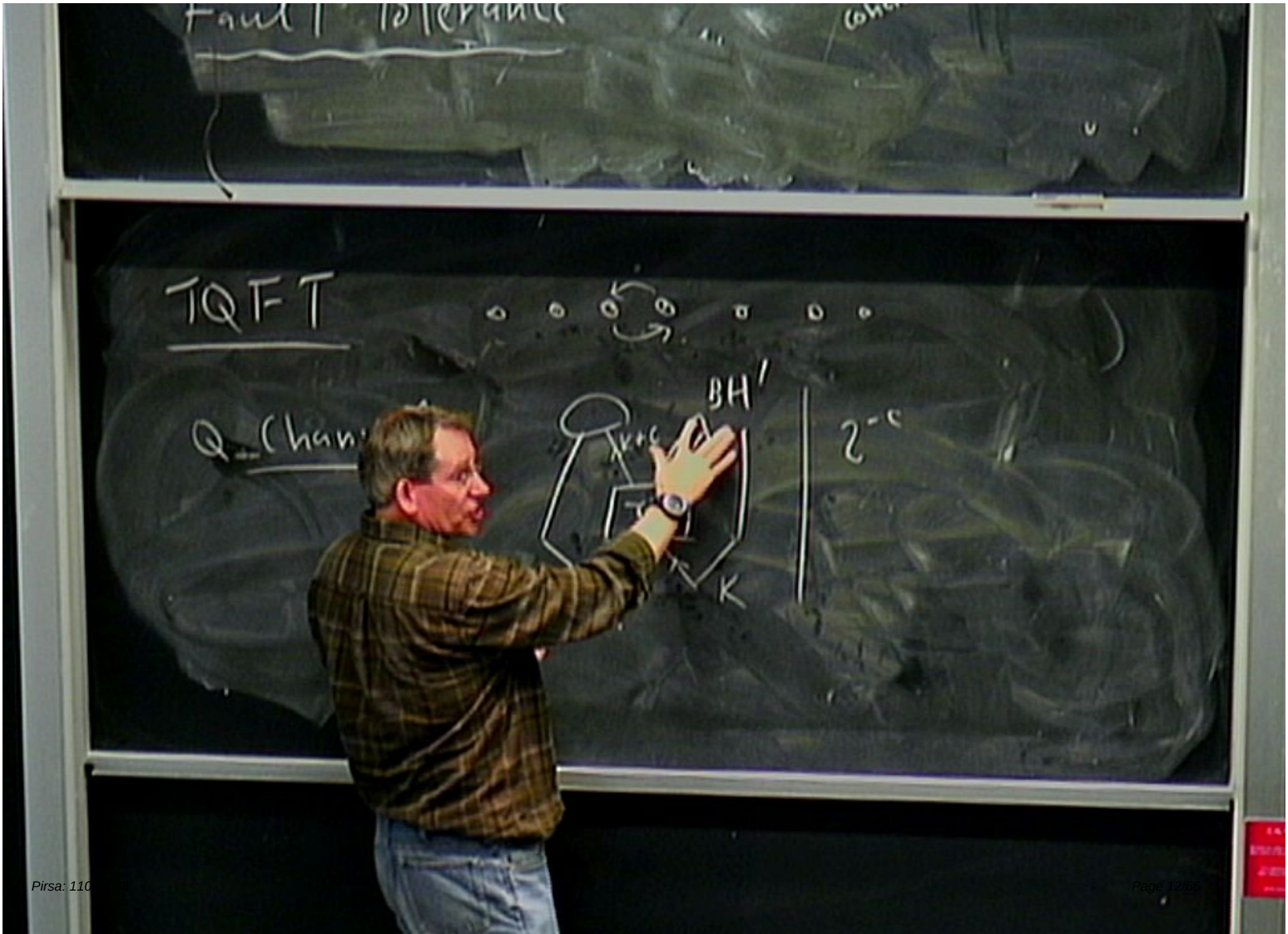

TQFT
Q-Channels


TQFT
BH'


TQFT
Q-Channels
BH'
BH
K

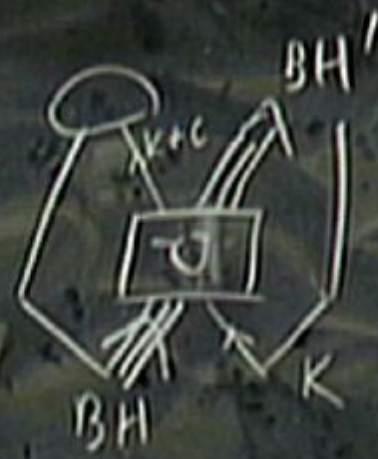

TQFT
Q-Channels
BH'
BH
K


TQFT
BH'
K

Fault Tolerance

TQFT

Q. Channels



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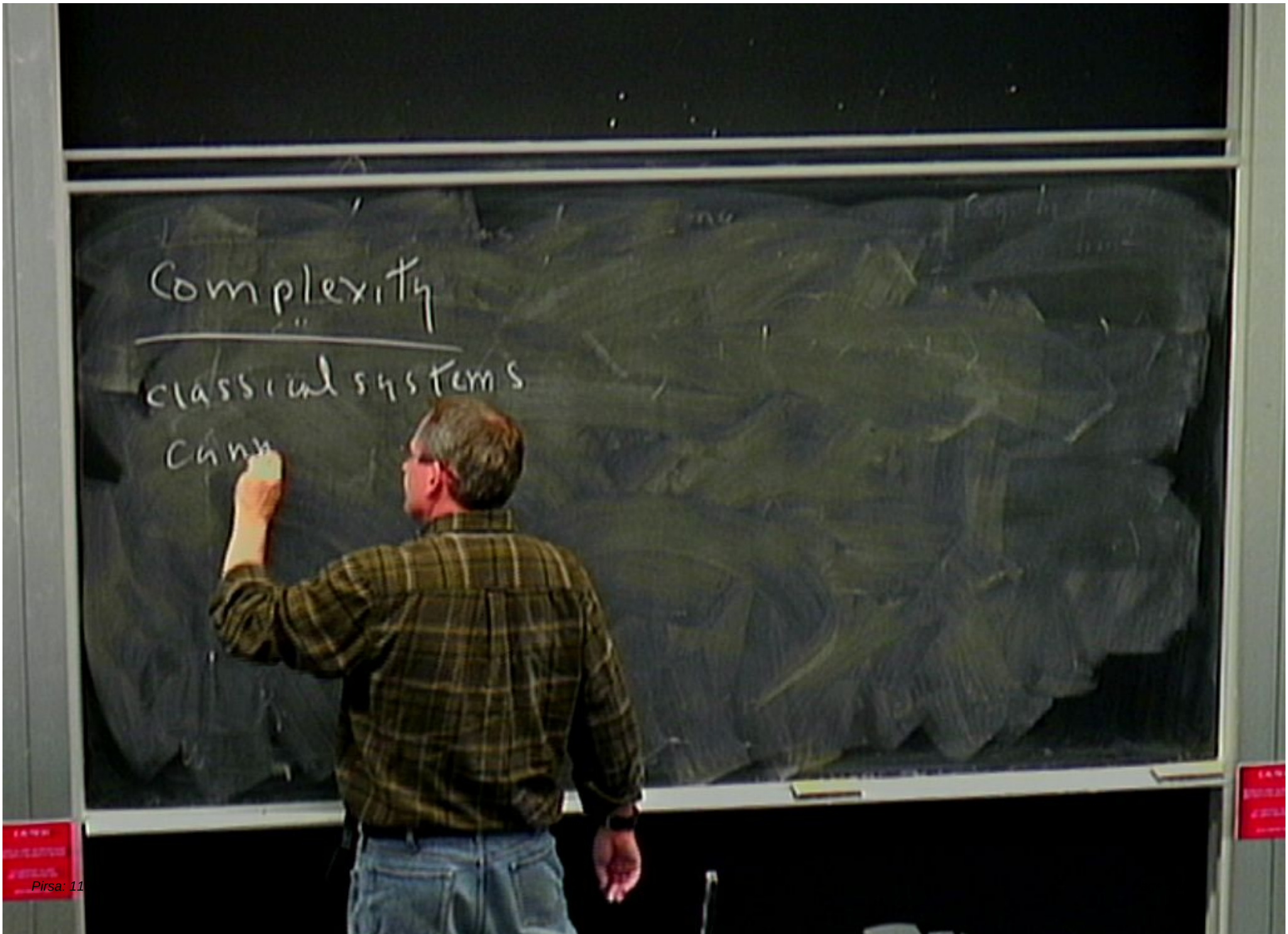
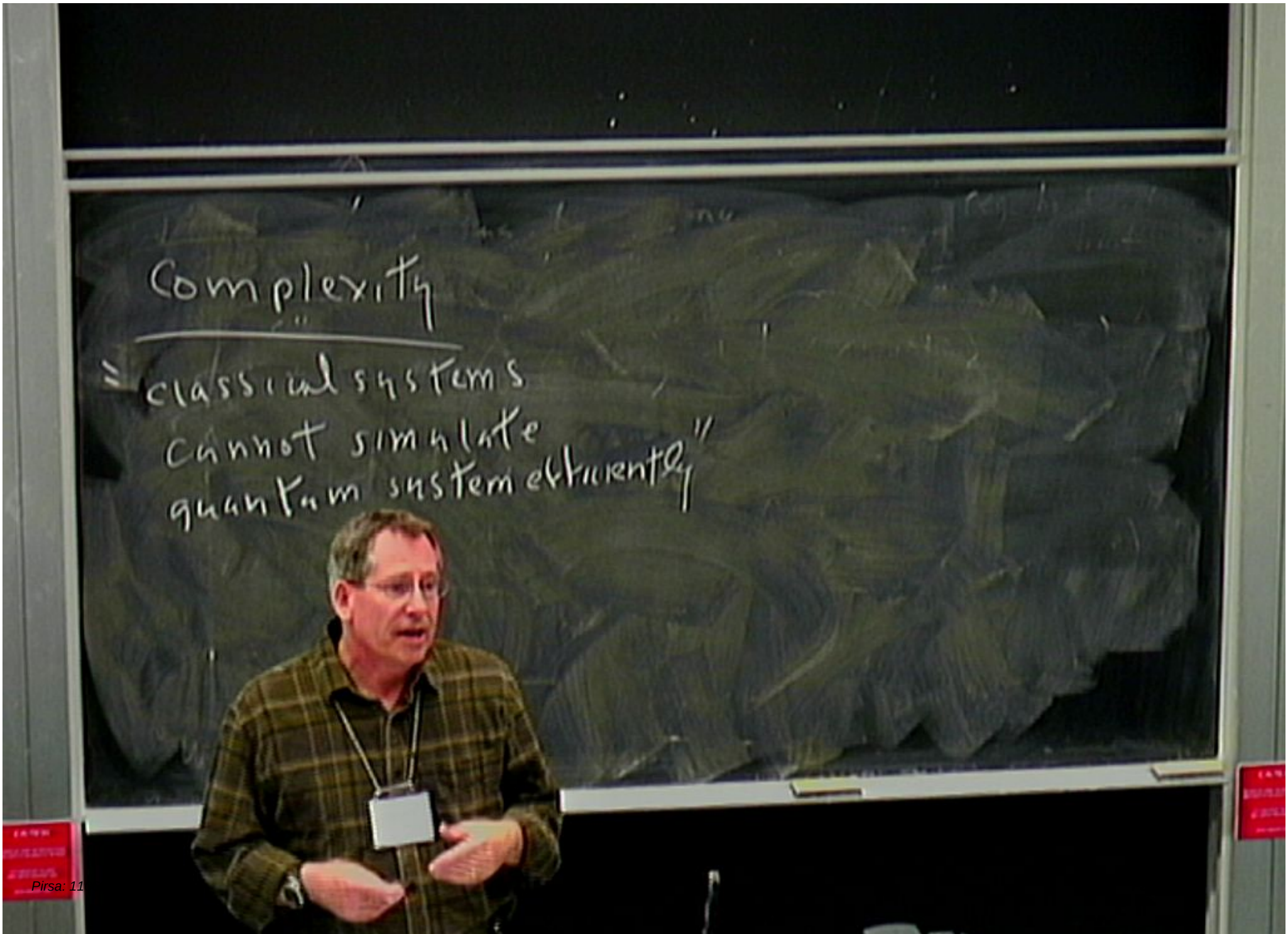
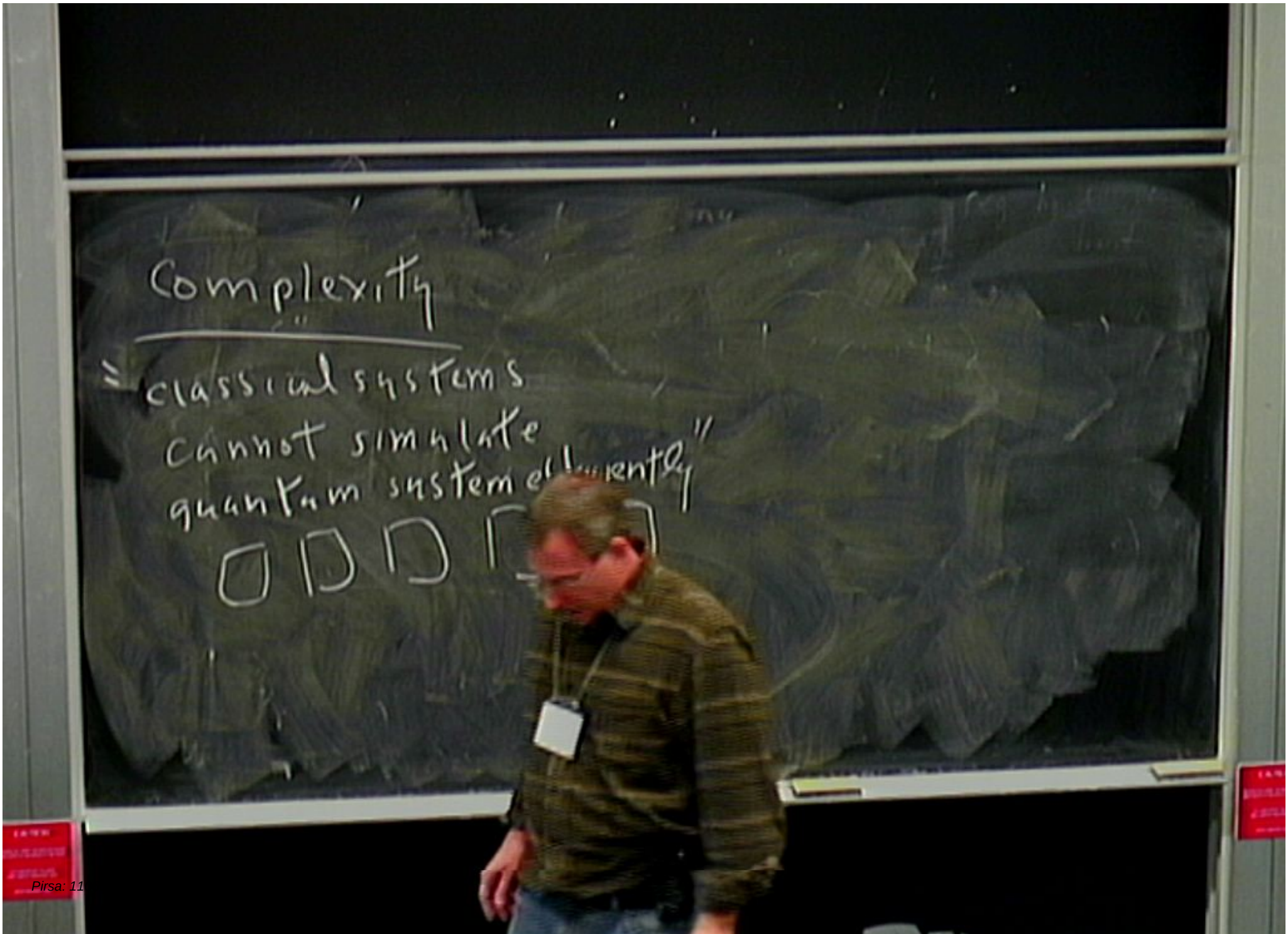

Complexity
classical systems


Complexity
= "classical systems
cannot simulate
quantum system efficiently"


Complexity
"classical systems
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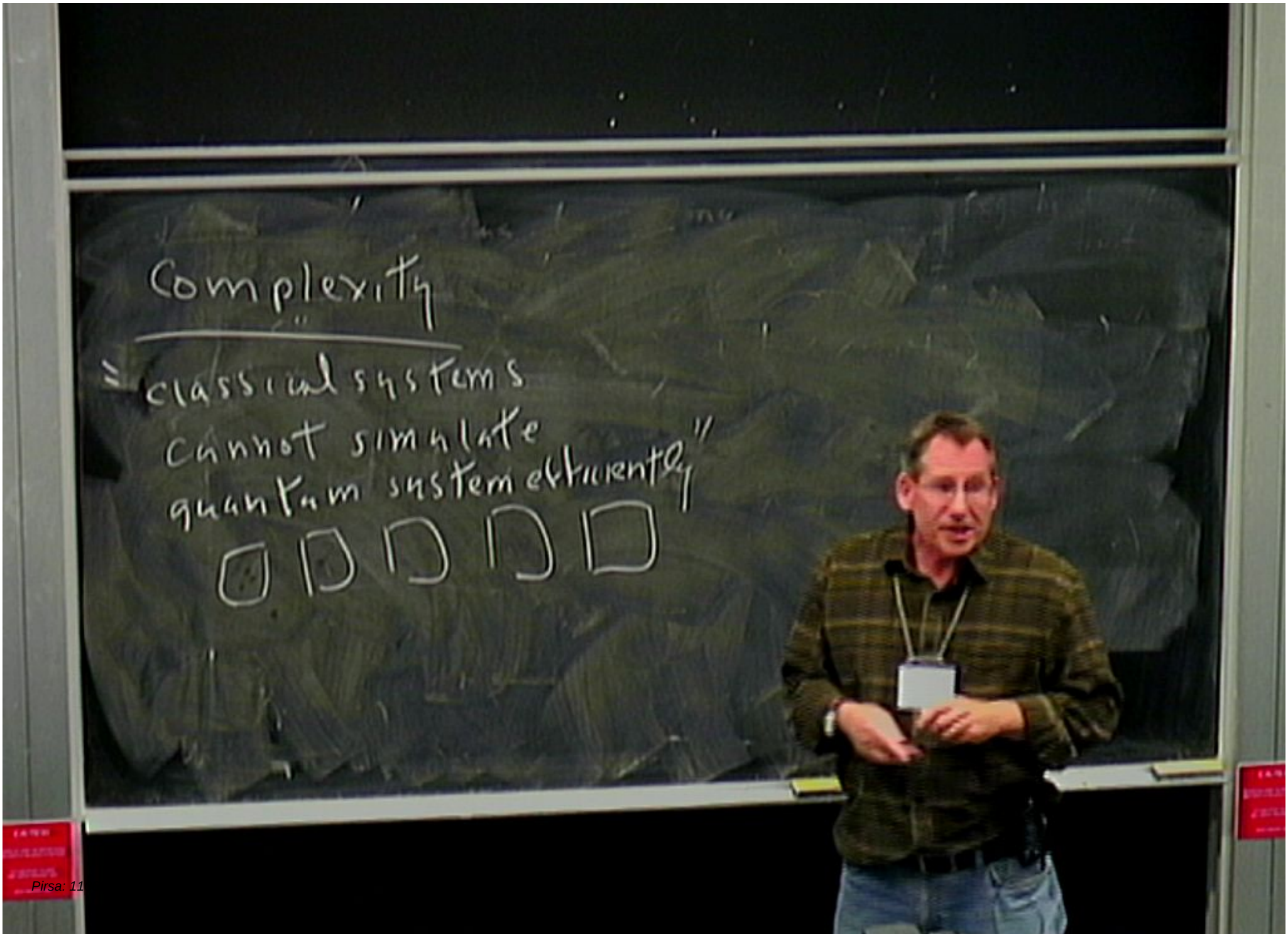
Complexity
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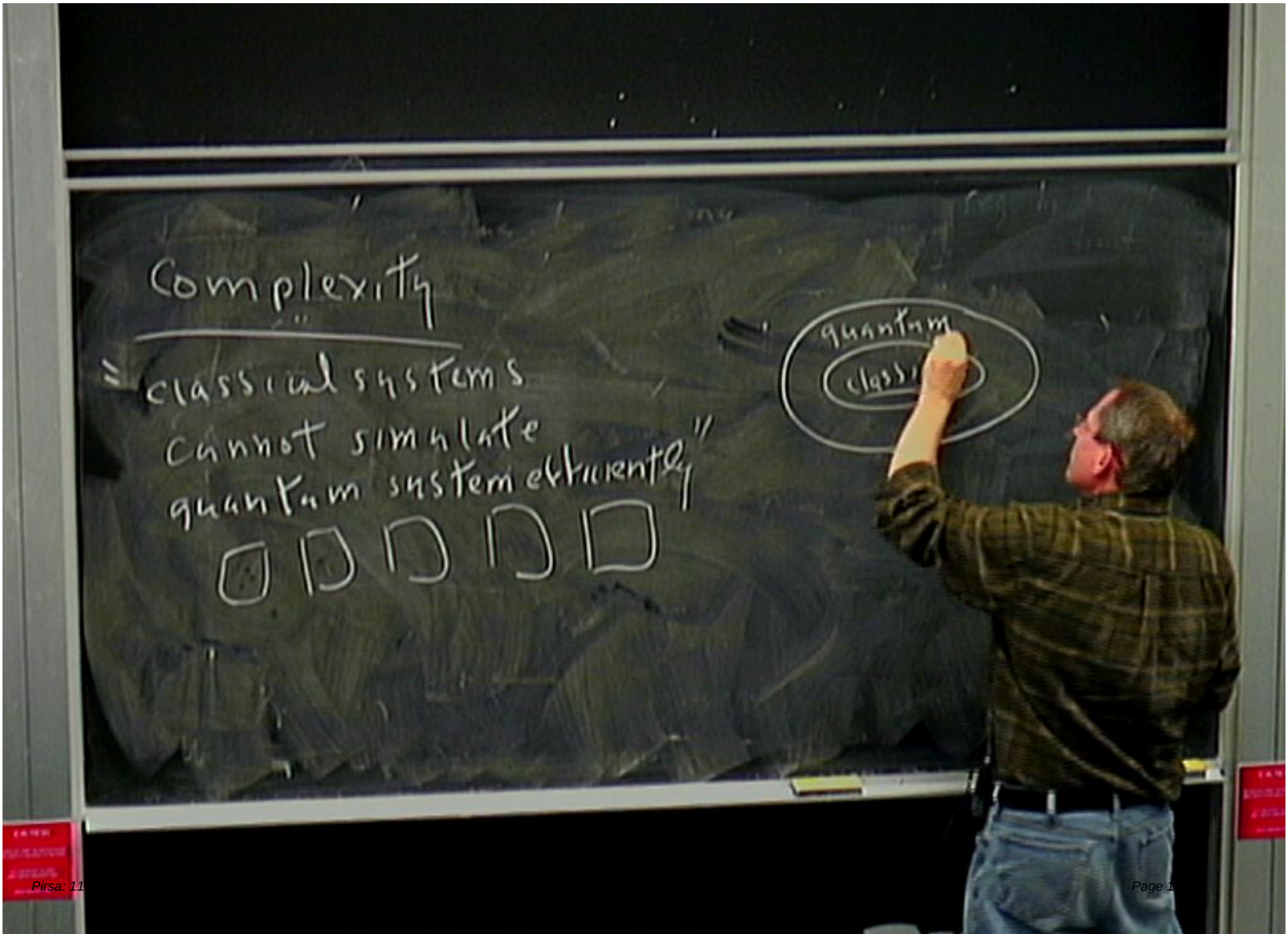
Complexity
"classical systems
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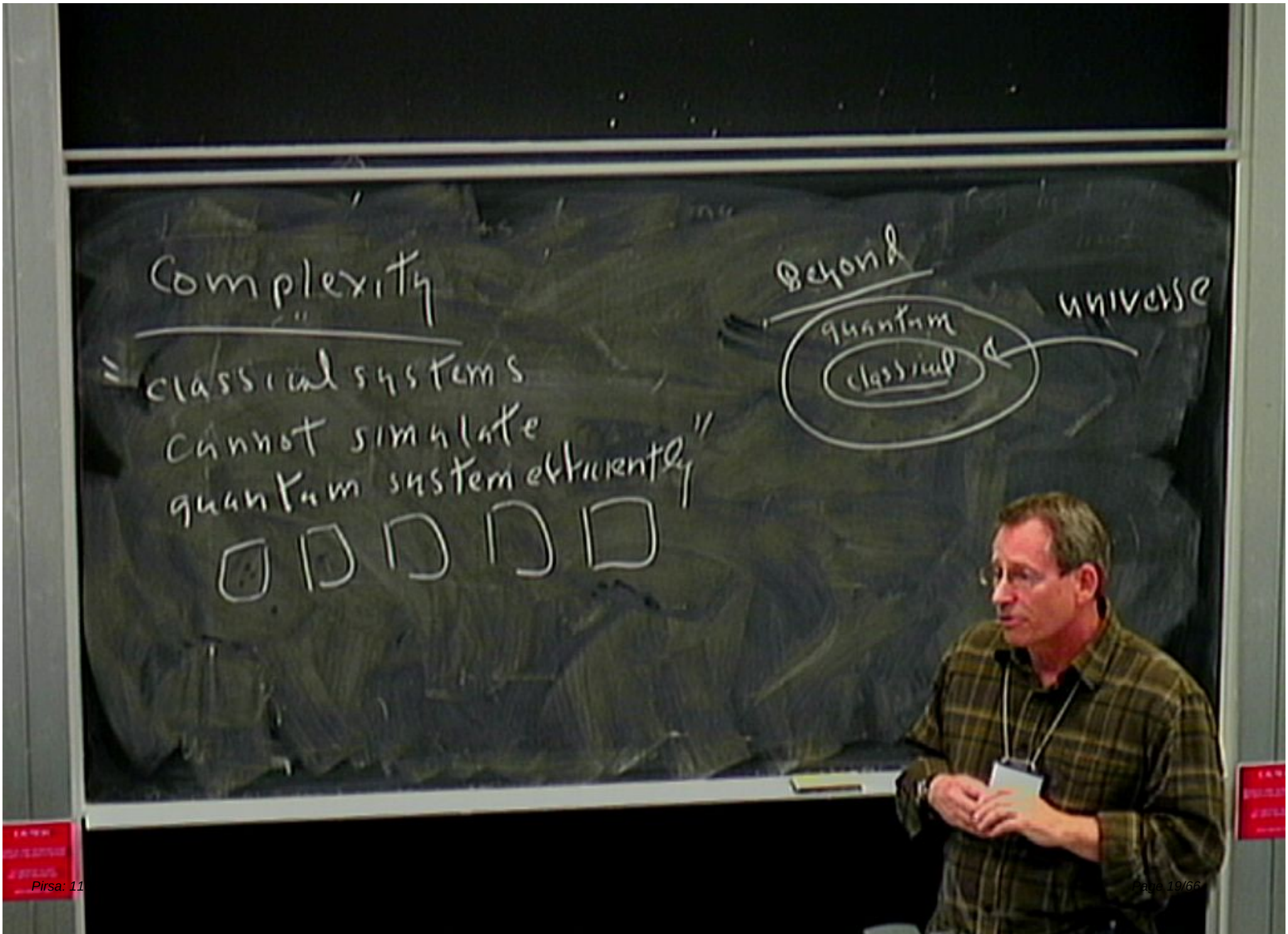
quantum
classical


Complexity
= "classical systems
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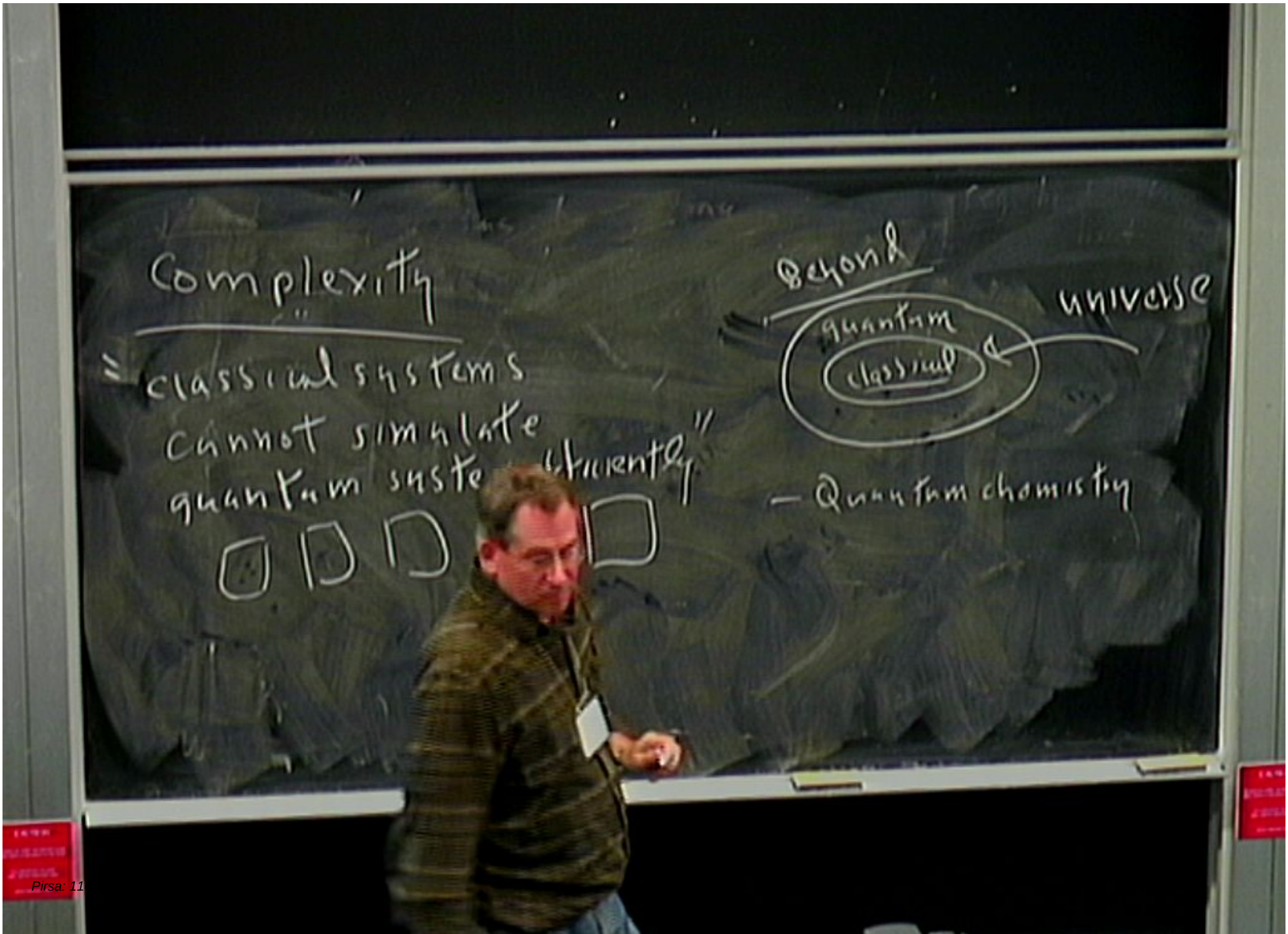
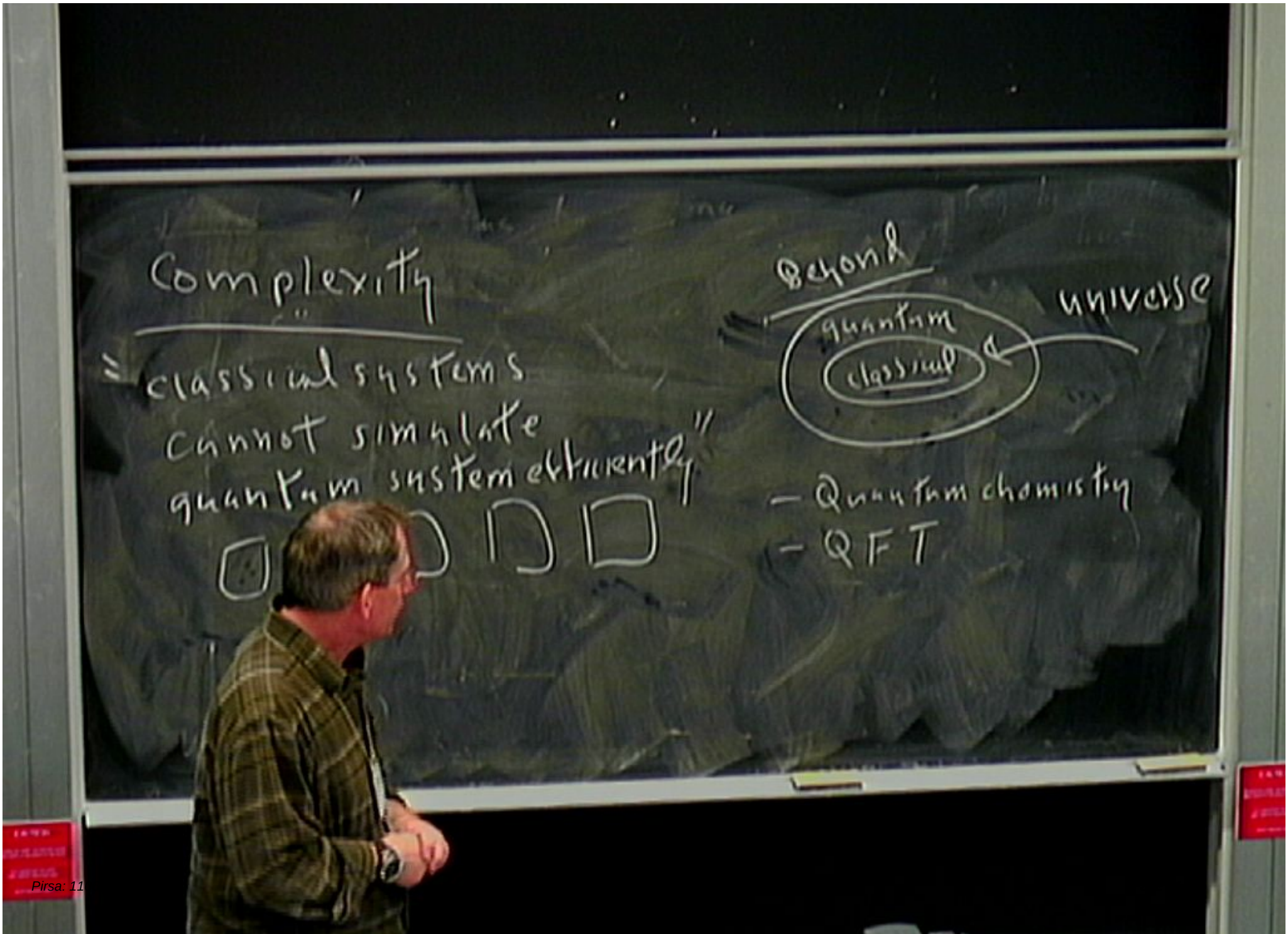
quantum system efficiently"
Beyond
universe
quantum
classical


Complexity
= classical systems
cannot simulate
quantum syste "intuition"
Beyond
universe
quantum
classical
– Quantum chemistry


Complexity
"classical systems
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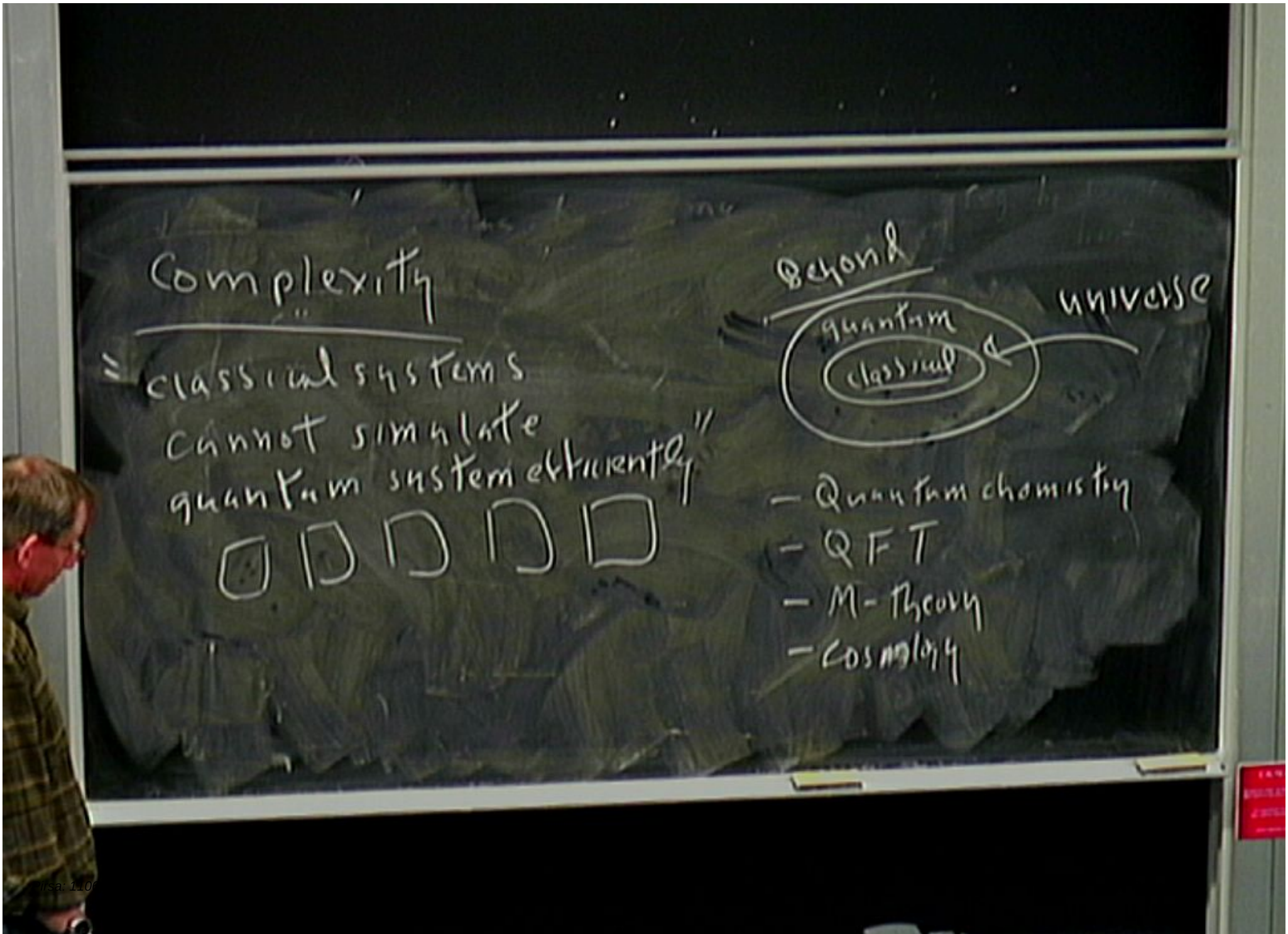
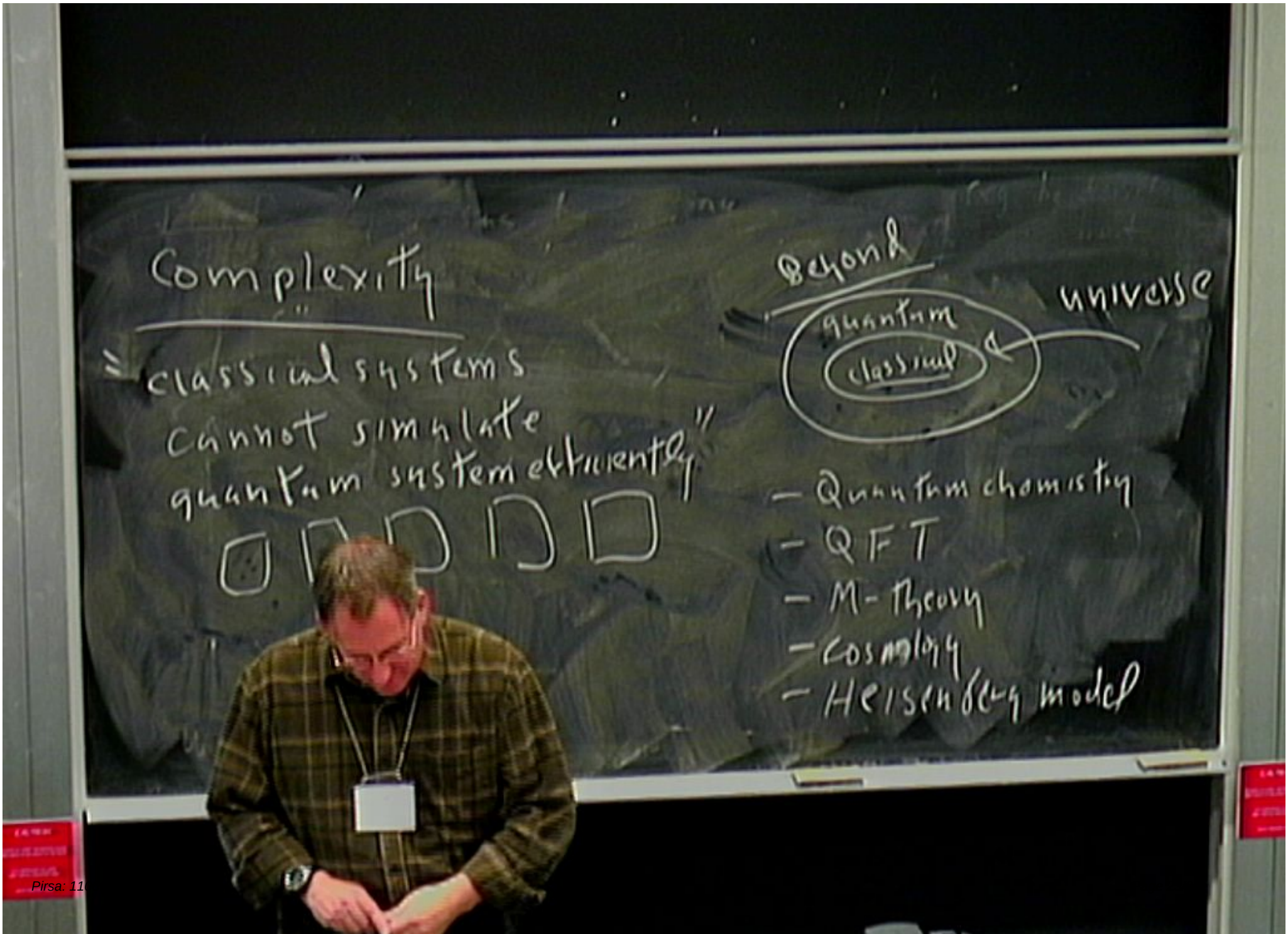
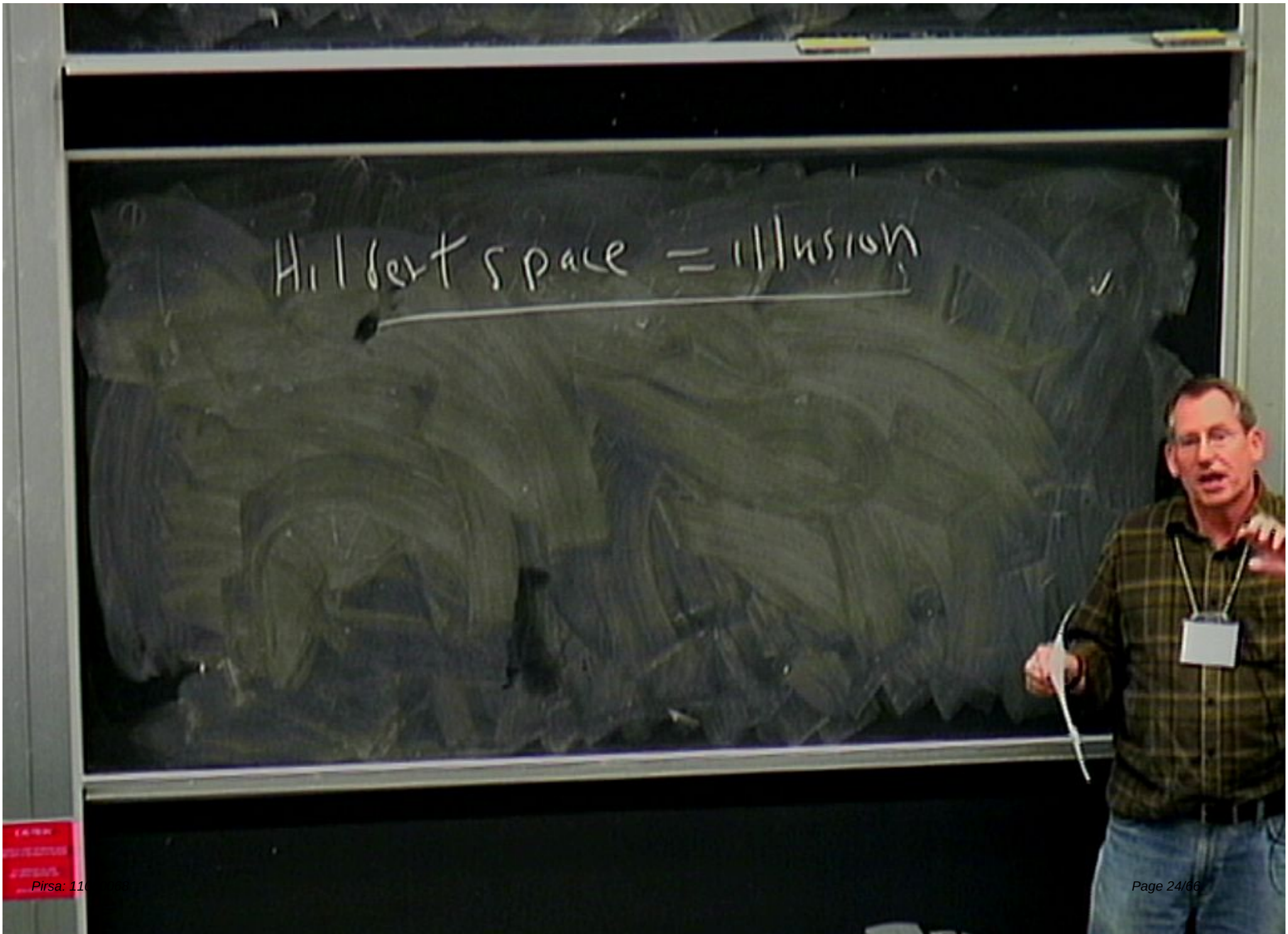
quantum system efficiently"
Beyond
universe
quantum
classical
- Quantum chemistry
- QFT


Complexity
= "classical systems
cannot simulate
quantum system efficiently"
Beyond
universe
quantum
classical
- Quantum chemistry
- QFT
- M-Theory
- Cosmology


Complexity
"classical systems
cannot simulate
quantum system efficiently"
beyond
universe
quantum
classical
- Quantum chemistry
- QFT
- M-Theory
- Cosmology
- Heisenberg model


Hilbert space = illusion

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Vol ~ $\exp(2^n)$ $\quad$ |product state⟩

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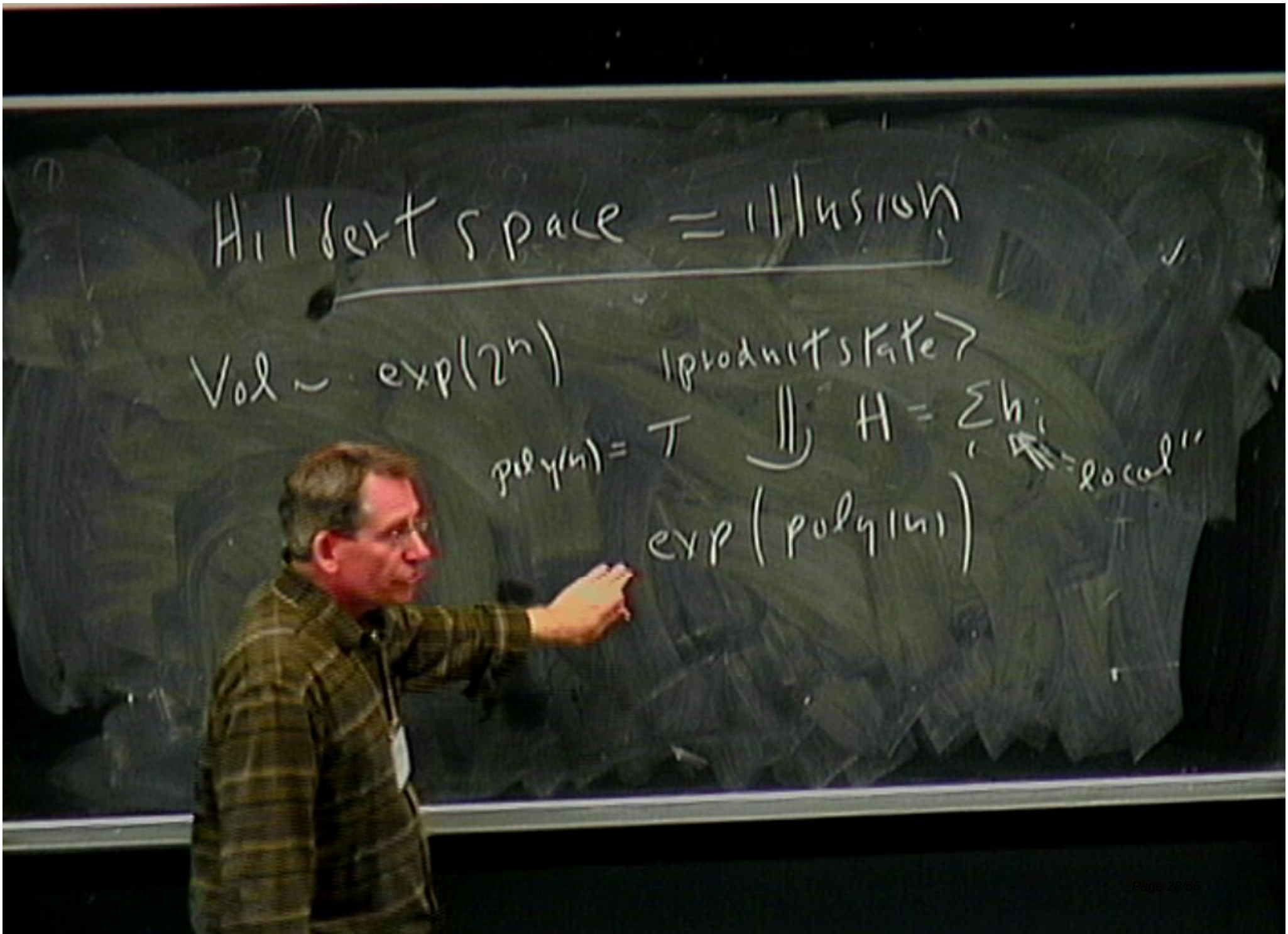
$\Downarrow$ $H = \sum_i h_i$ "local"

Hilbert space = illusion

Vol ~ exp(2^n) |product state⟩

poly(n) = T $\Downarrow$ $H = \sum_i h_i$ "local"


Hilbert space = illusion
Vol ~ exp(2^n)
|product state>
poly(n) = T
H = Σ h_i
"local"
exp(poly(n))

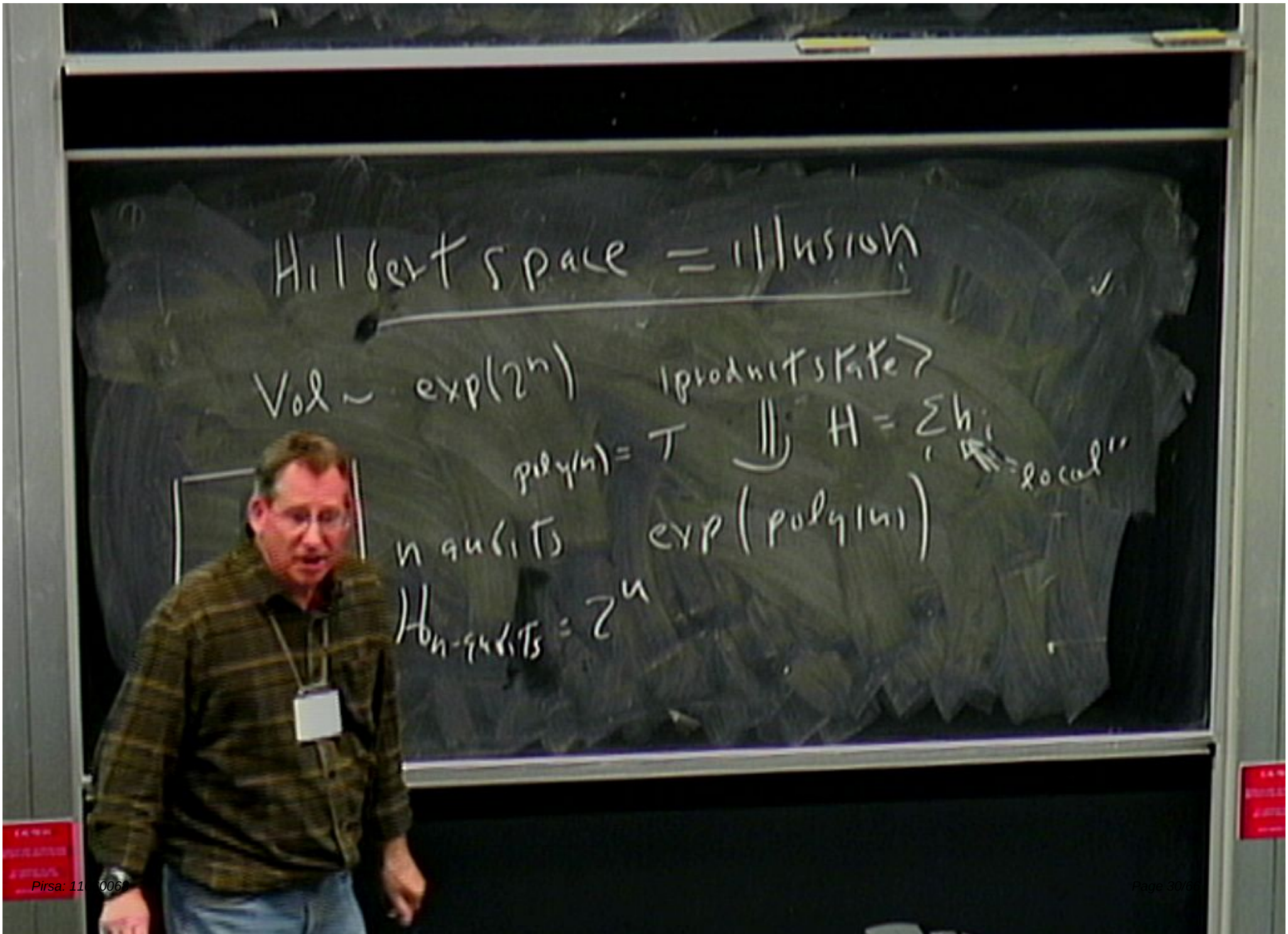
Hilbert space = illusion

Vol ~ $\exp(2^n)$

$|\text{product state}\rangle$

poly(n) = T $\Downarrow$ $H = \sum_i h_i$ "local"

$\exp(\text{poly}(n))$


Hilbert space = illusion
Vol ~ exp(2^n)
|product state>
poly(n) = T
H = Σ h_i
"local"
n qubits
exp(poly(n))
H_n-qubits = 2^n

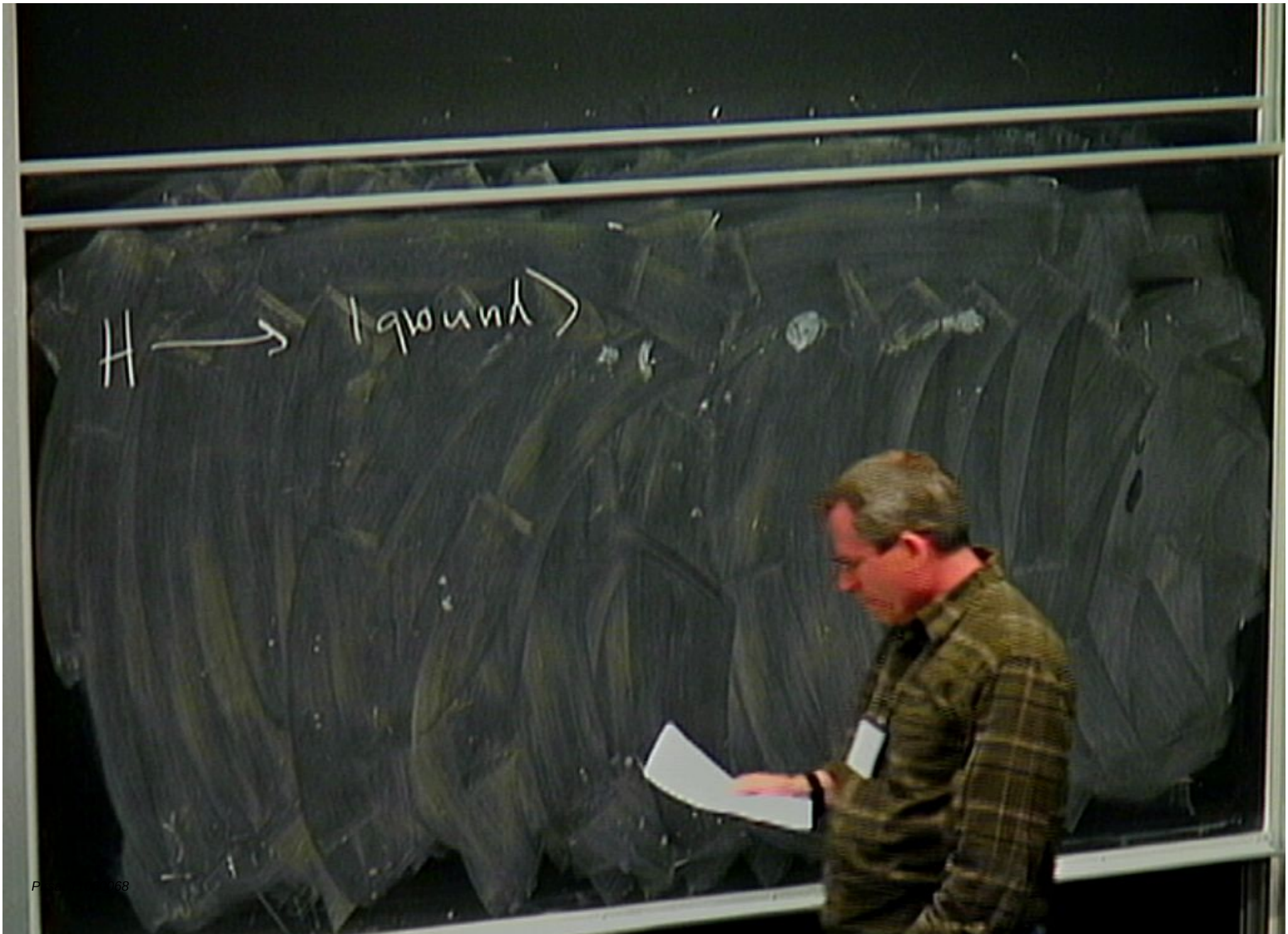
Hilbert space = illusion

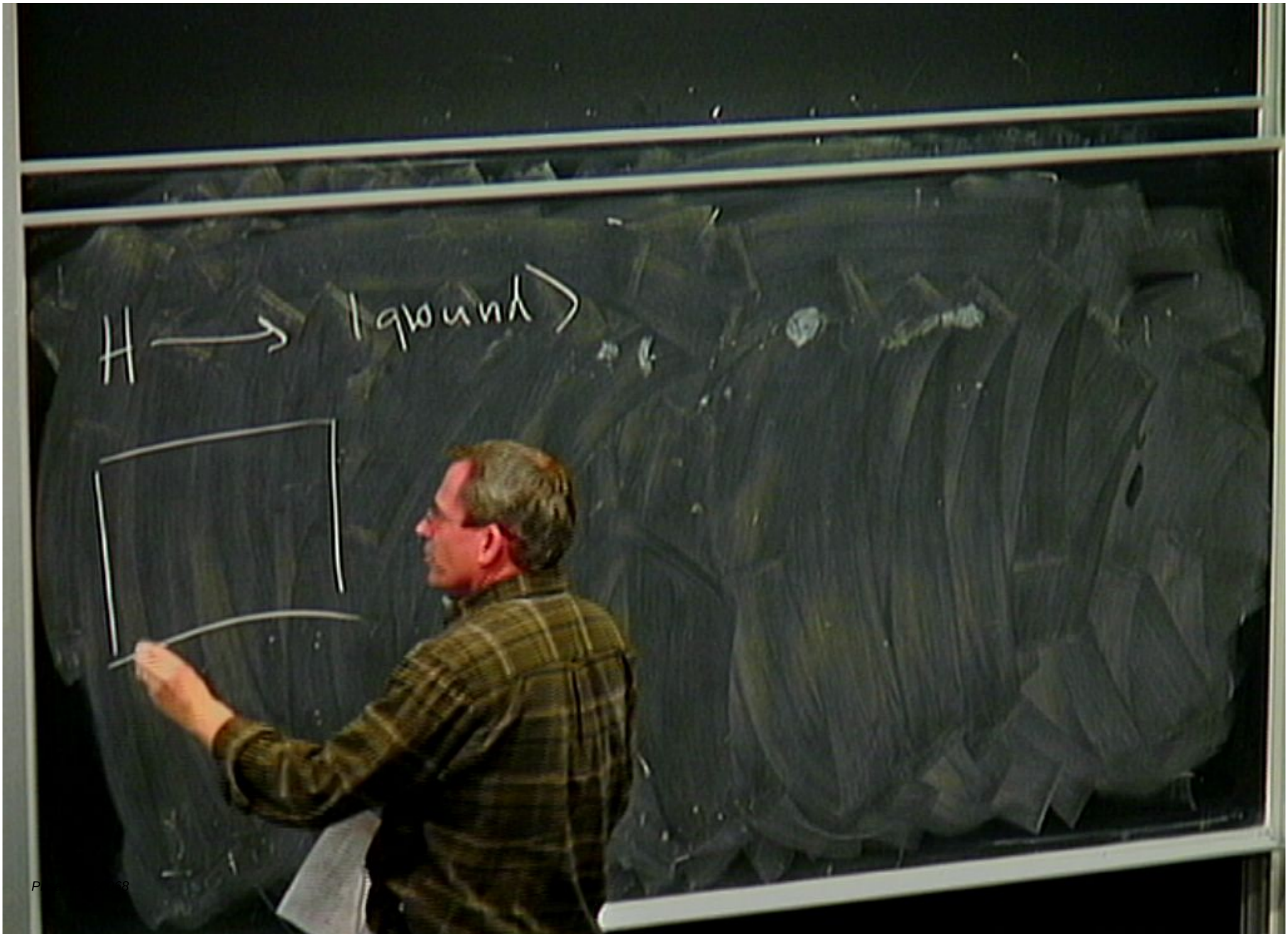
Vol ~ exp(2^n) |product state⟩

poly(n) = T $\Downarrow$ $H = \sum h_i$ "local"

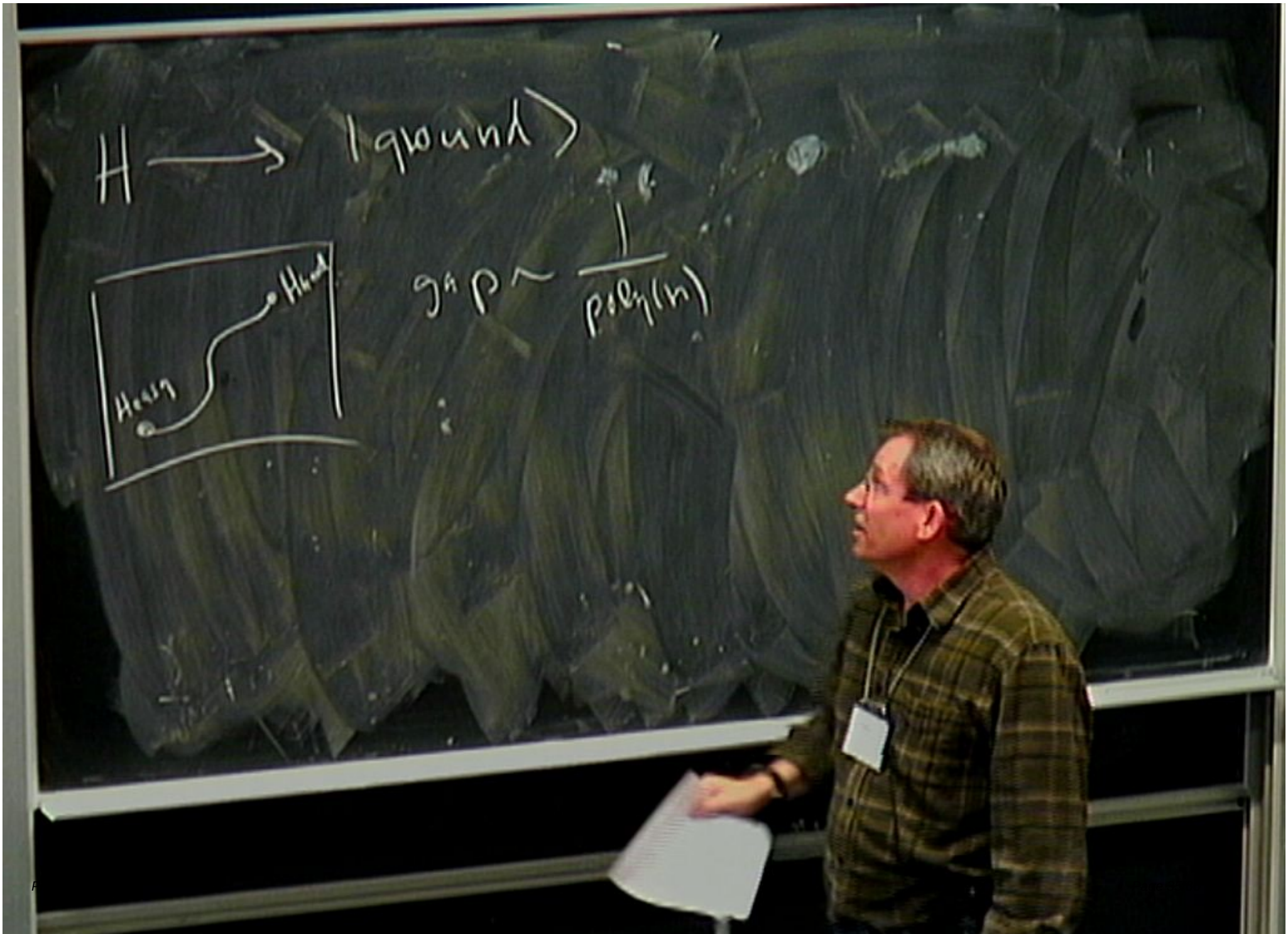
n qubits exp(poly(n))

$\mathcal{H}_{n\text{-qubits}} = 2^n$


H → |ground⟩

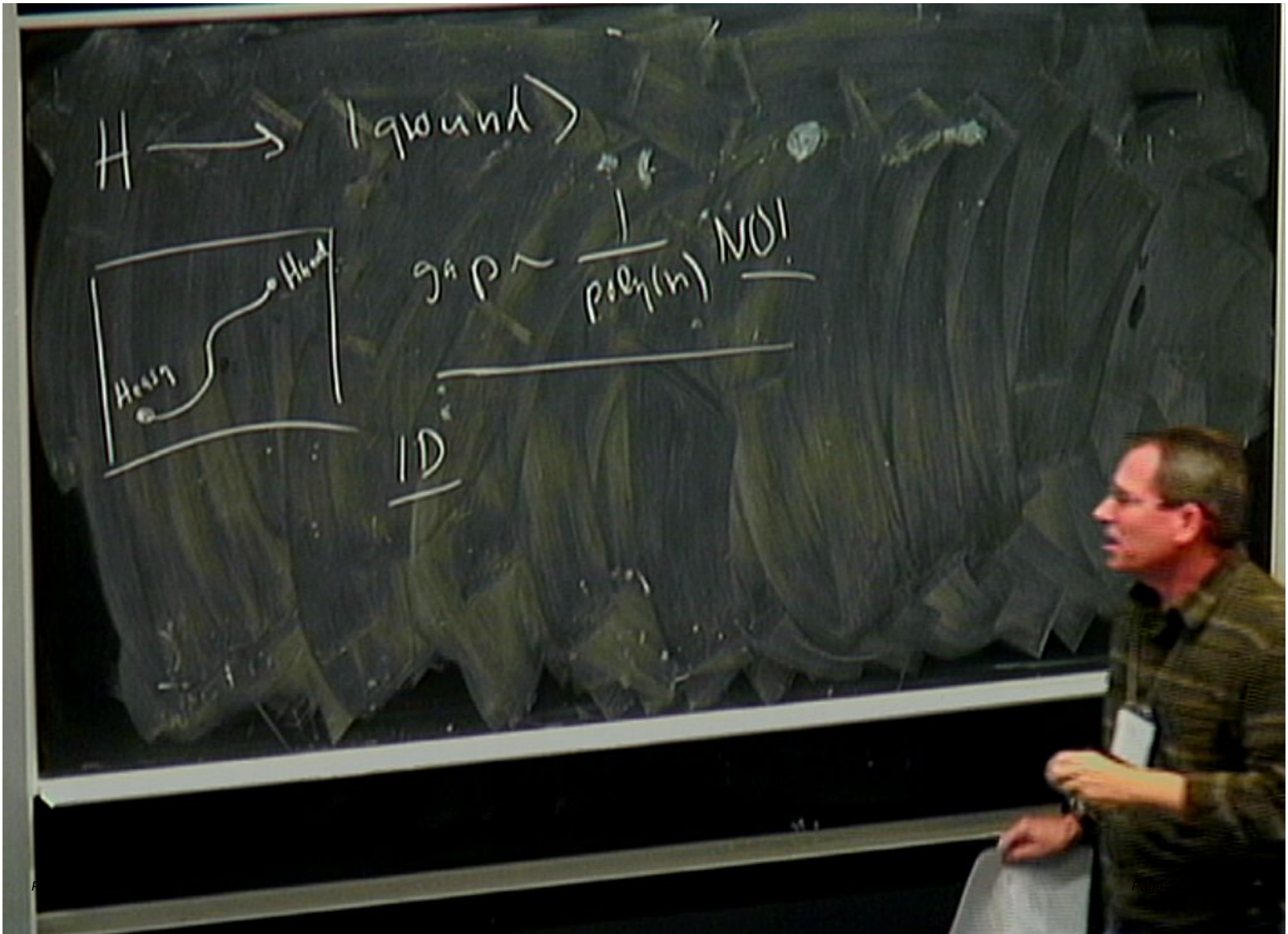

H → |ground⟩

$H \longrightarrow |\text{ground}\rangle$


H → |ground⟩
gap ~ 1/poly(n)

$H \longrightarrow |\text{ground}\rangle$

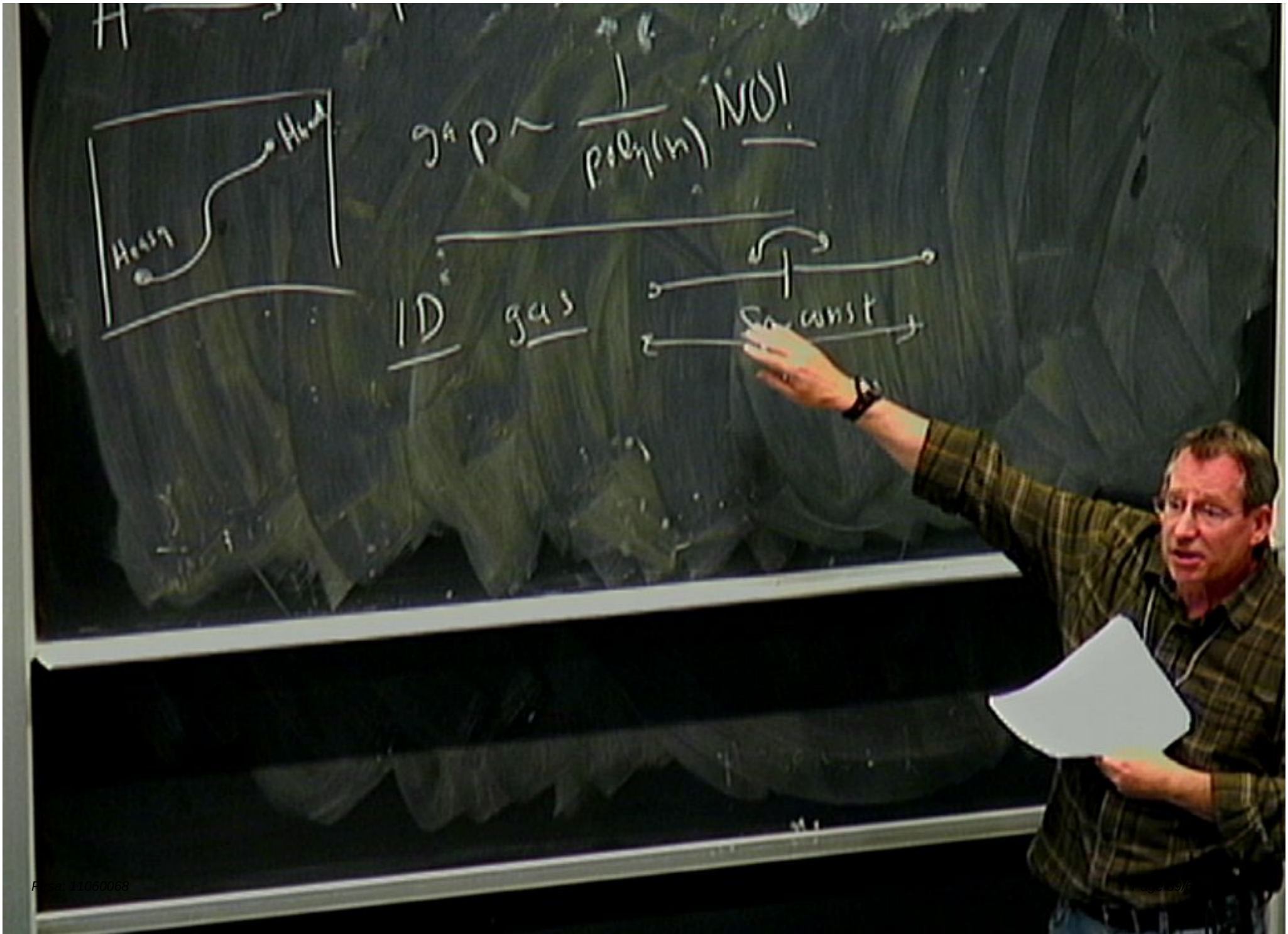
$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

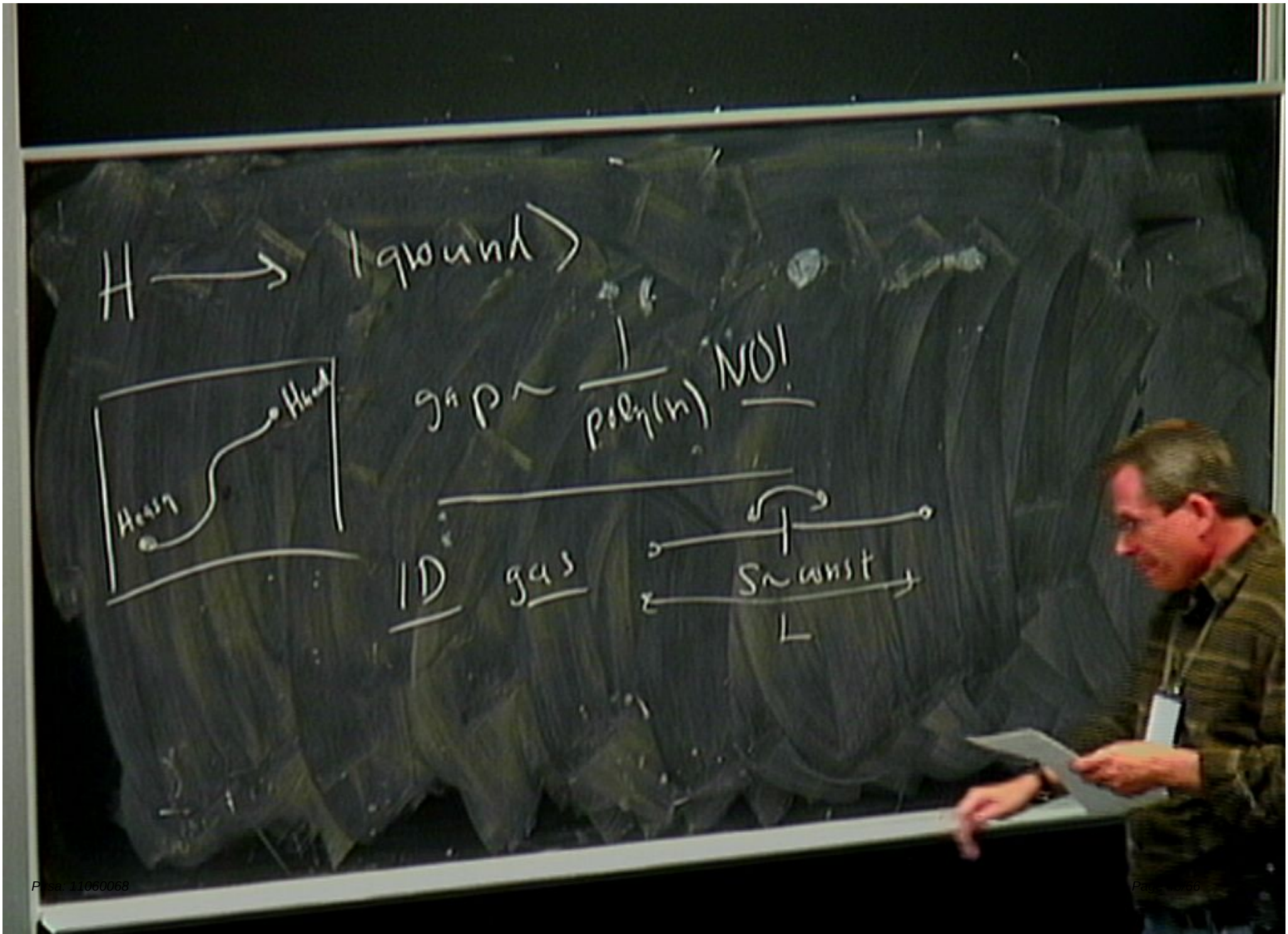

H → |ground⟩
gap ~ 1/poly(n)
NO!
1D

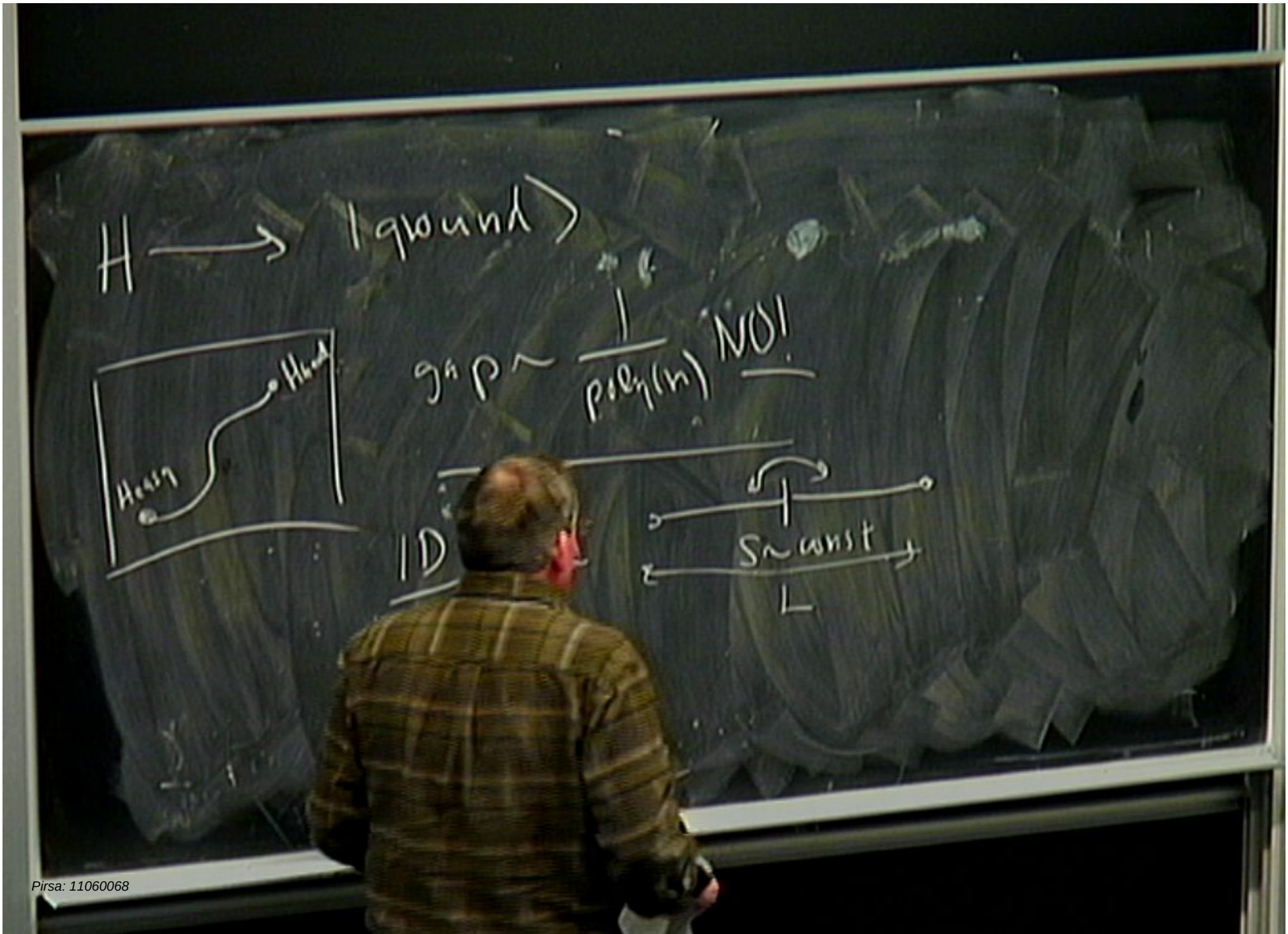
$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

1D gas


gap ~ 1/poly(n) NO!
1D gas
const


H → |ground>
gap ~ 1/poly(n) NO!
1D gas
S ~ const
L


H → |ground⟩
gap ~ 1/poly(n) NO!
Hard
Hard
1D
S ~ const
L

$H \longrightarrow |\text{ground}\rangle$

gap $\sim \frac{1}{\text{poly}(n)}$ NO!

1D gapless

$S \sim \text{const}$

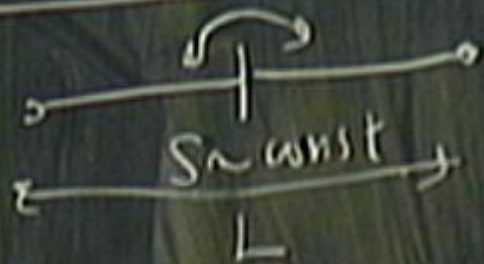
L

gapless

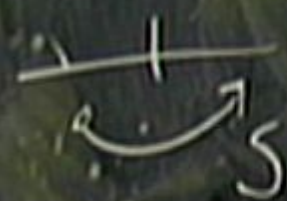
$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

1D gapped



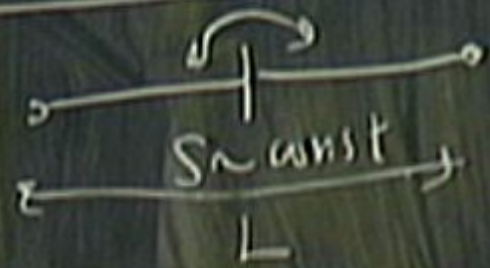
gapless



$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

1D gapped



gapless

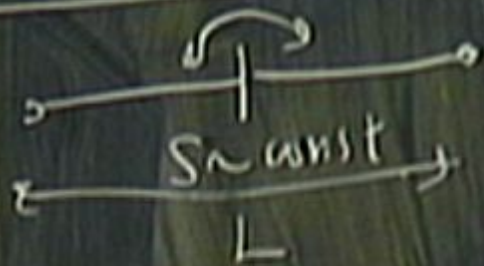
$S \sim \frac{c}{3} \ln L$

$H \longrightarrow |\text{ground}\rangle$

gap $\sim \frac{1}{\text{poly}(n)}$ NO!

MERA

1D gap



gapless

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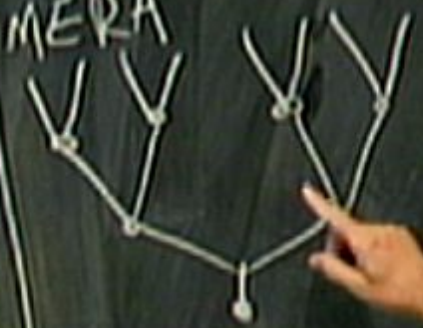
MERA



1D gapped

$S \sim \text{const}$

L

gapless

$S \sim \frac{c}{3} \ln L$

$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

1D gap

$S \sim \text{const}$

L

gapless

$S \sim \frac{c}{3} \ln L$

$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

1D gapped

$S \sim \text{const}$

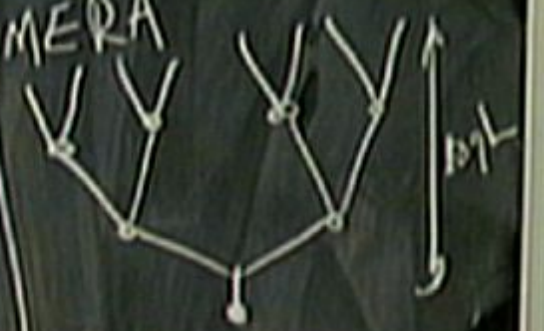
L

gapless

$S \sim \frac{c}{3} \ln L$

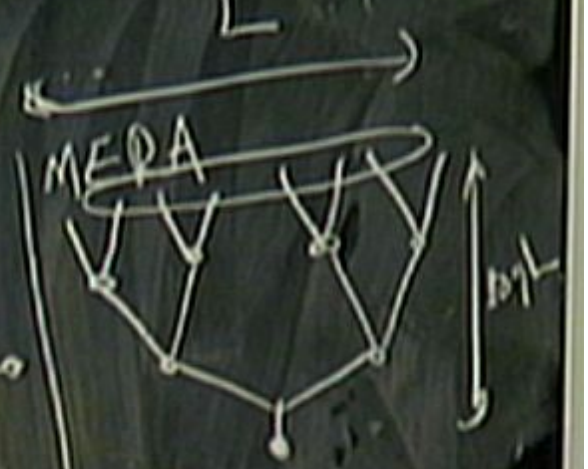
L

MERA



$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!



1D gap

$S \sim \text{const}$

L

gapless

$S \sim \frac{c}{3} \ln L$

$H \longrightarrow |\text{ground}\rangle$

gap $\sim \frac{1}{\text{poly}(n)}$ NO!

1D gapped

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gapless

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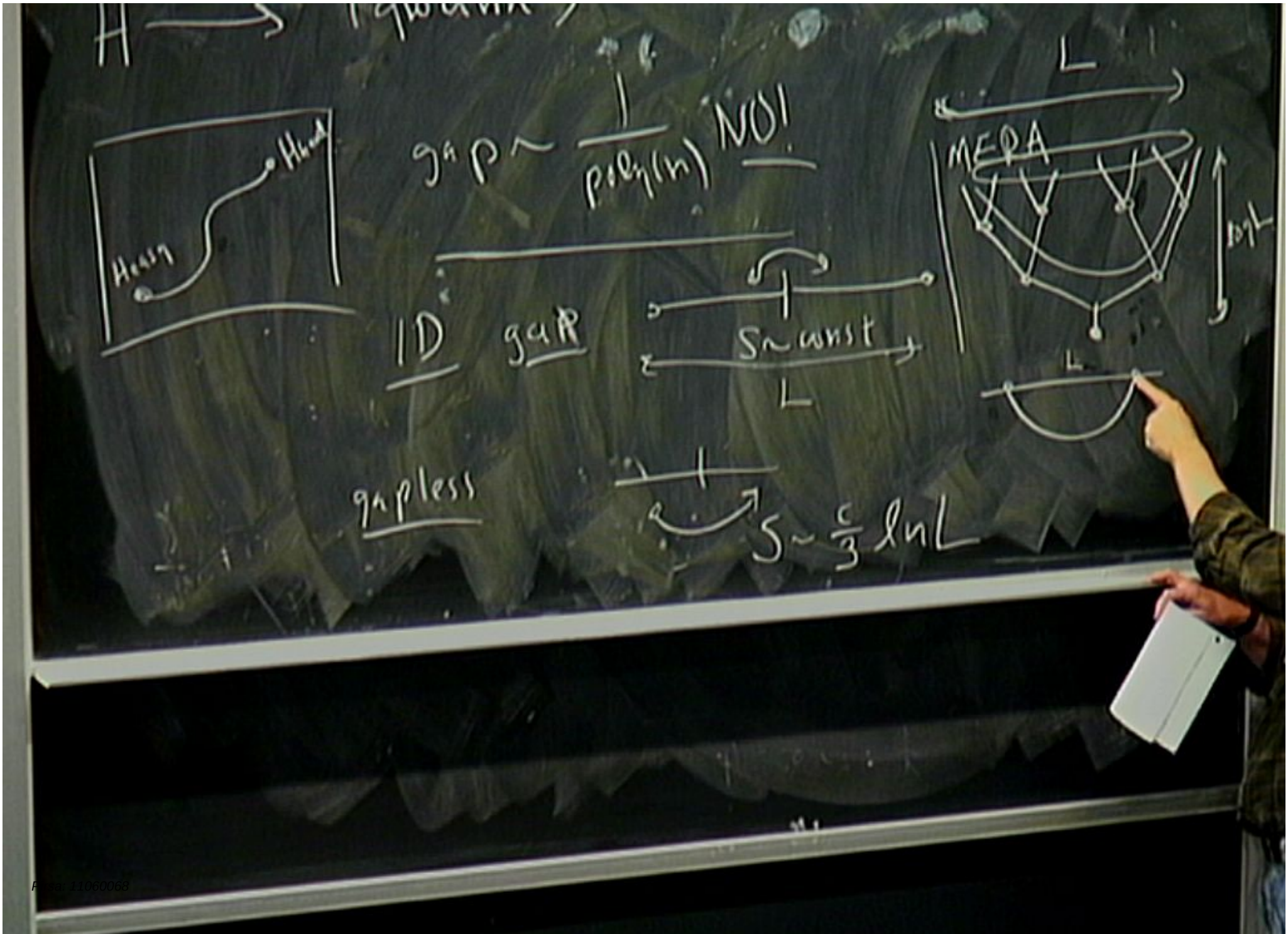


$H \longrightarrow |\text{ground}\rangle$

$\text{gap} \sim \frac{1}{\text{poly}(n)}$ NO!

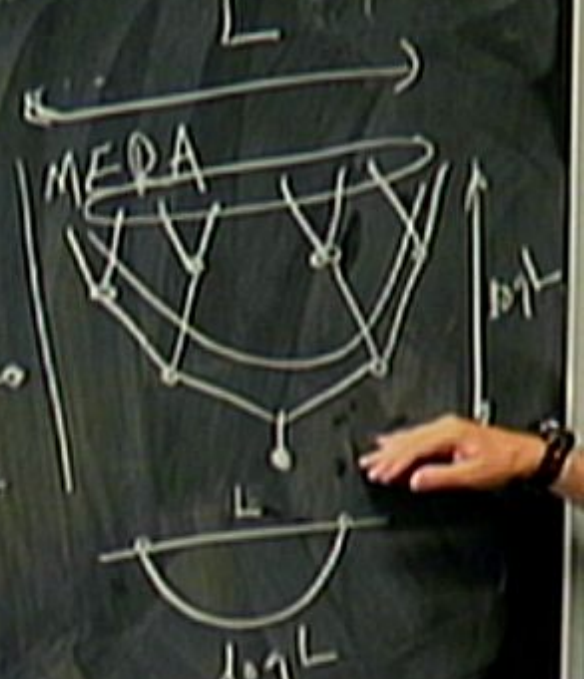
1D gapped

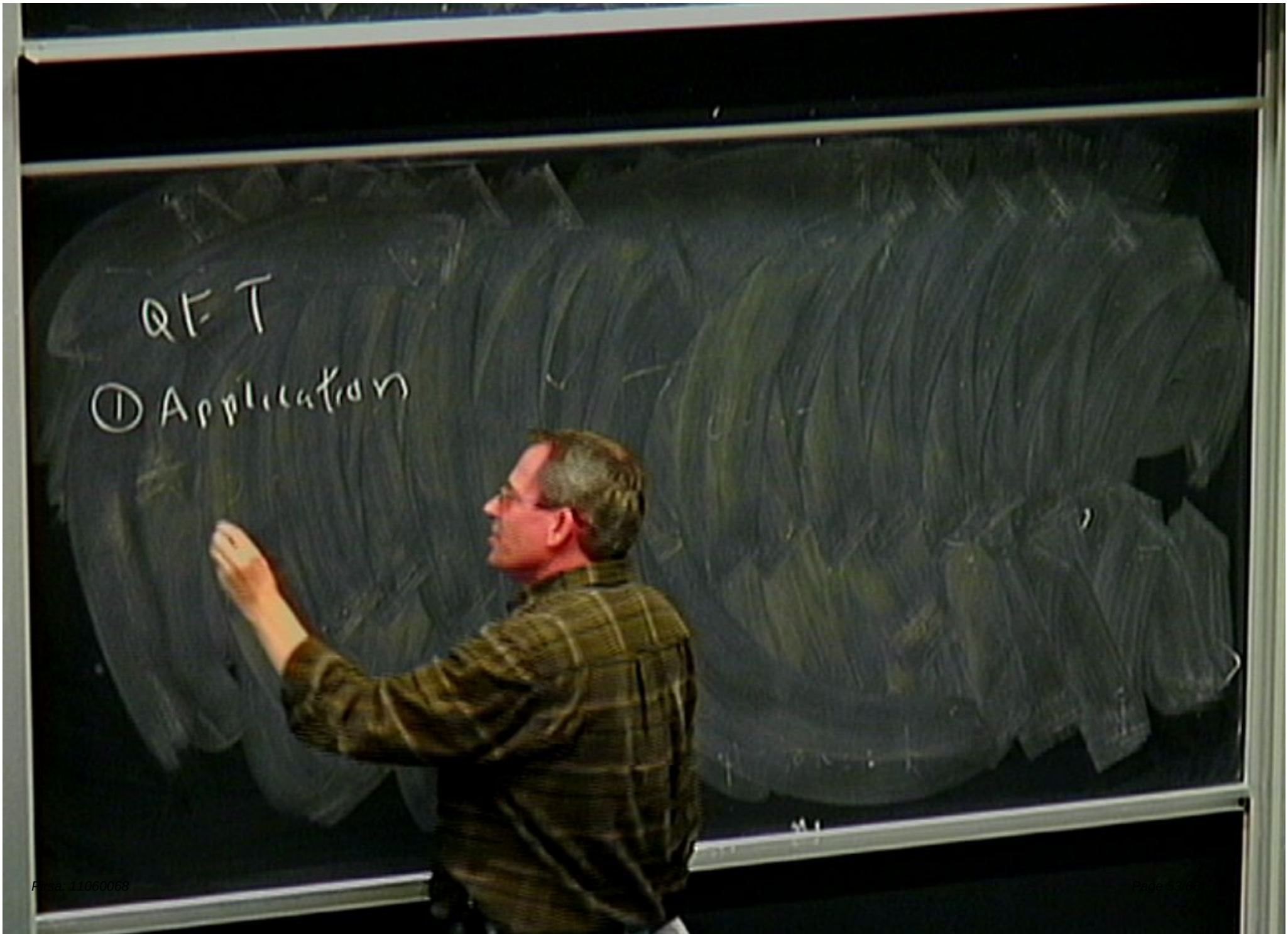
$S \sim \text{const}$

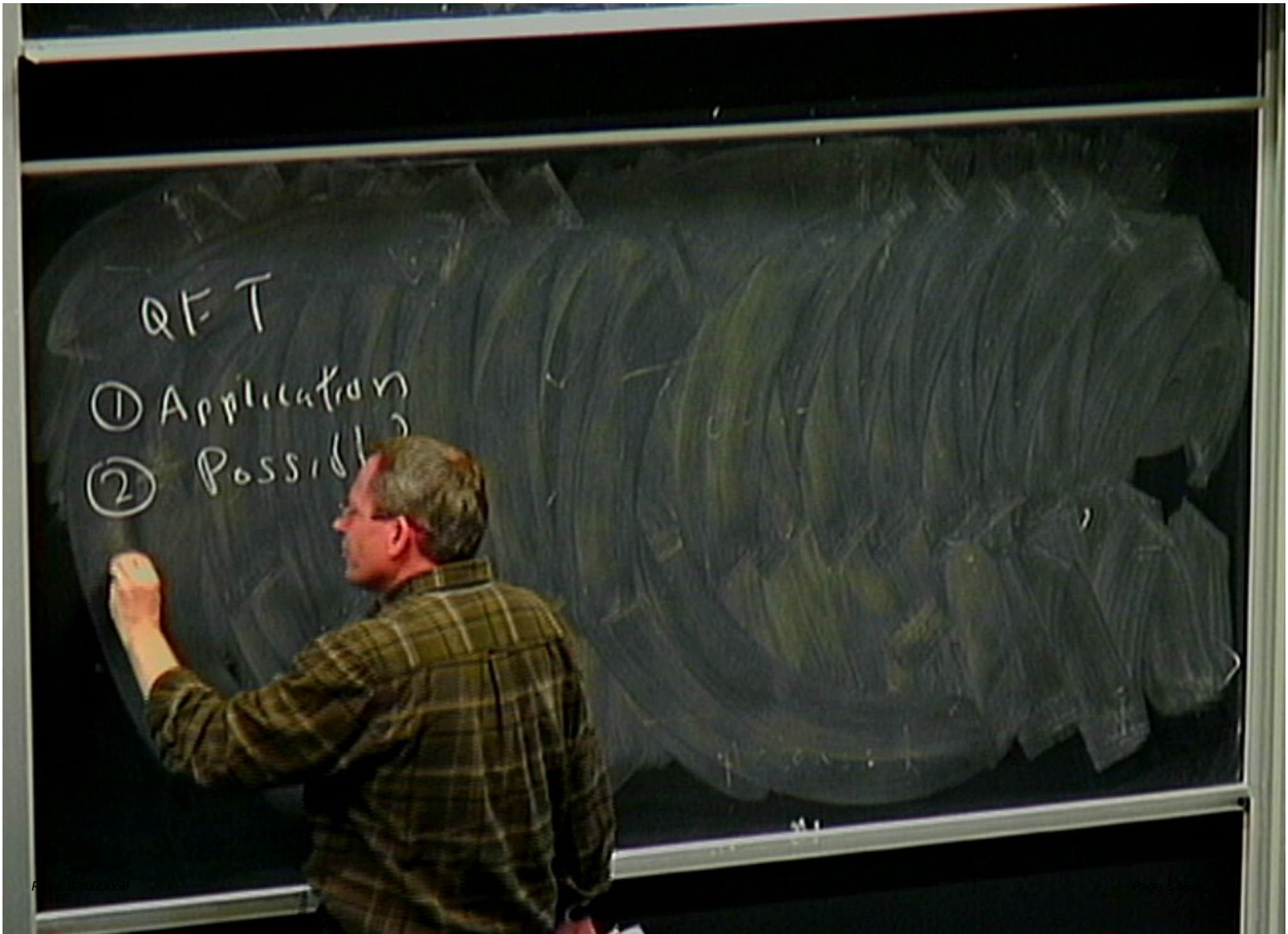
L

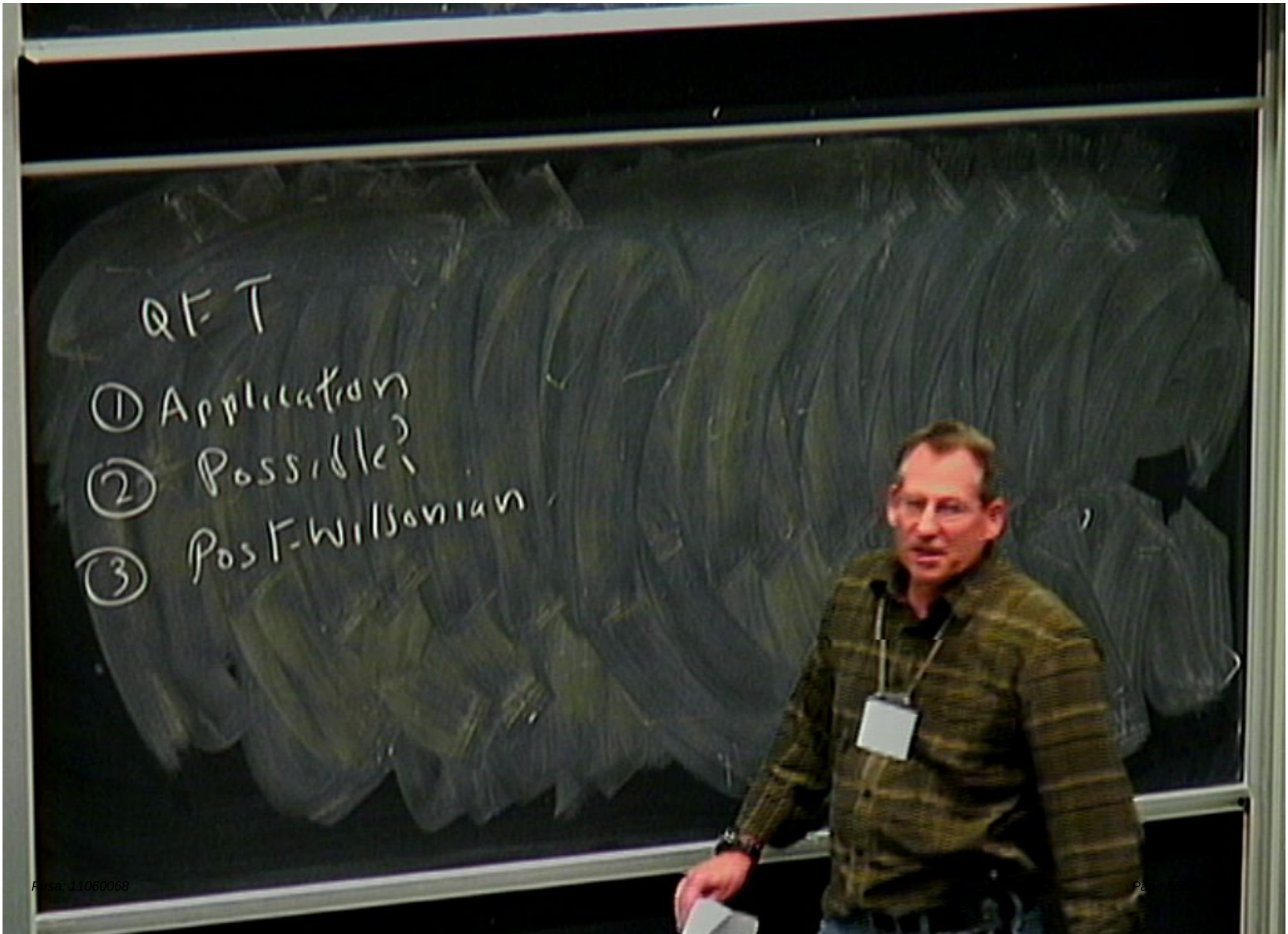
gapless

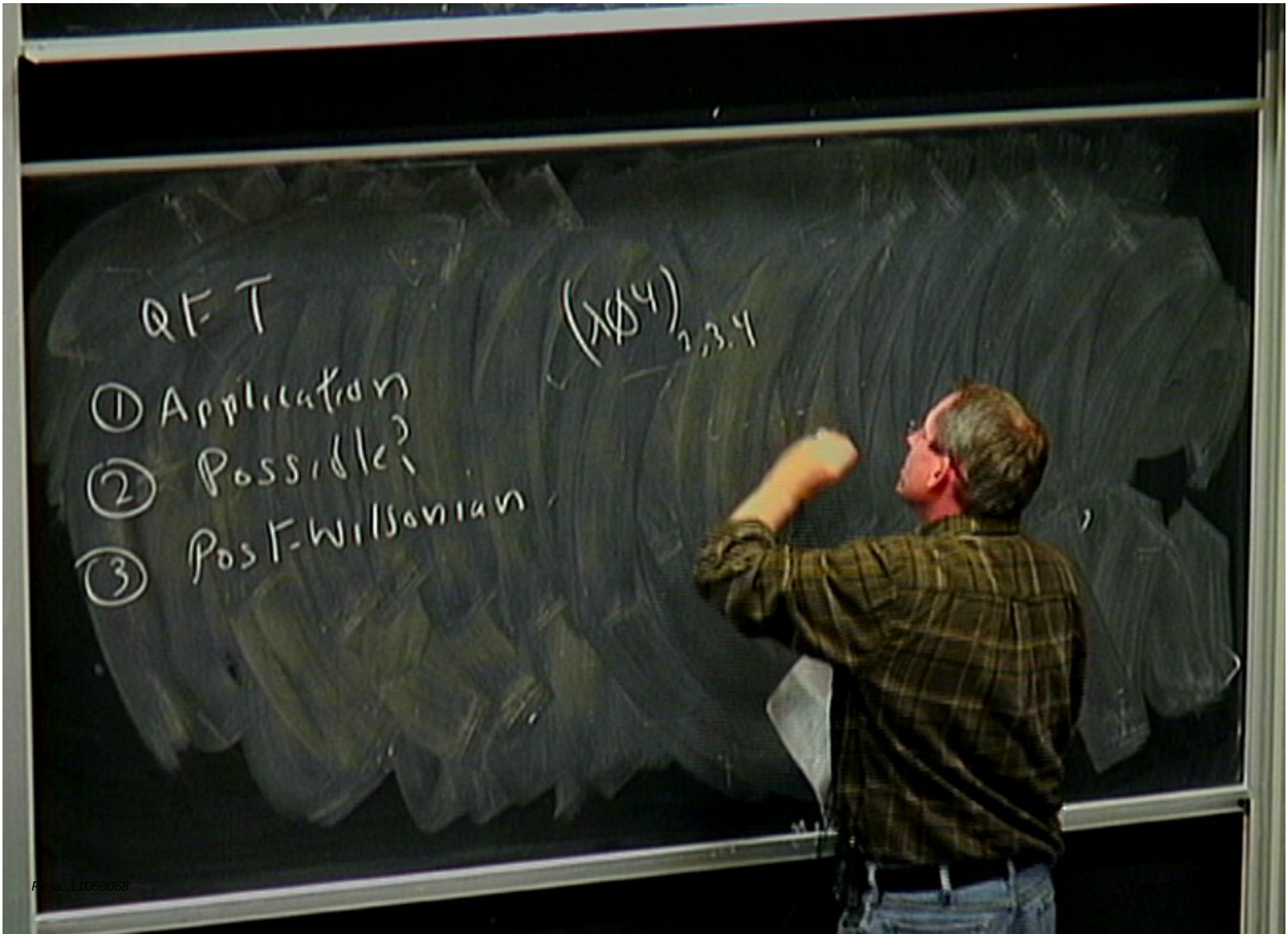
$S \sim \frac{c}{3} \ln L$




QFT
① Application


QFT
① Application
② Possibl


QFT
① Application
② Possible?
③ Post-Wilsonian


QFT
$(\lambda\phi^4)_{2,3,4}$
① Application
② Possible?
③ Post-Wilsonian

QFT

$(\lambda\phi^4)_{2,3,4}$

① Application

② Possible?

③ Post-Wilsonian

QFT

① Application

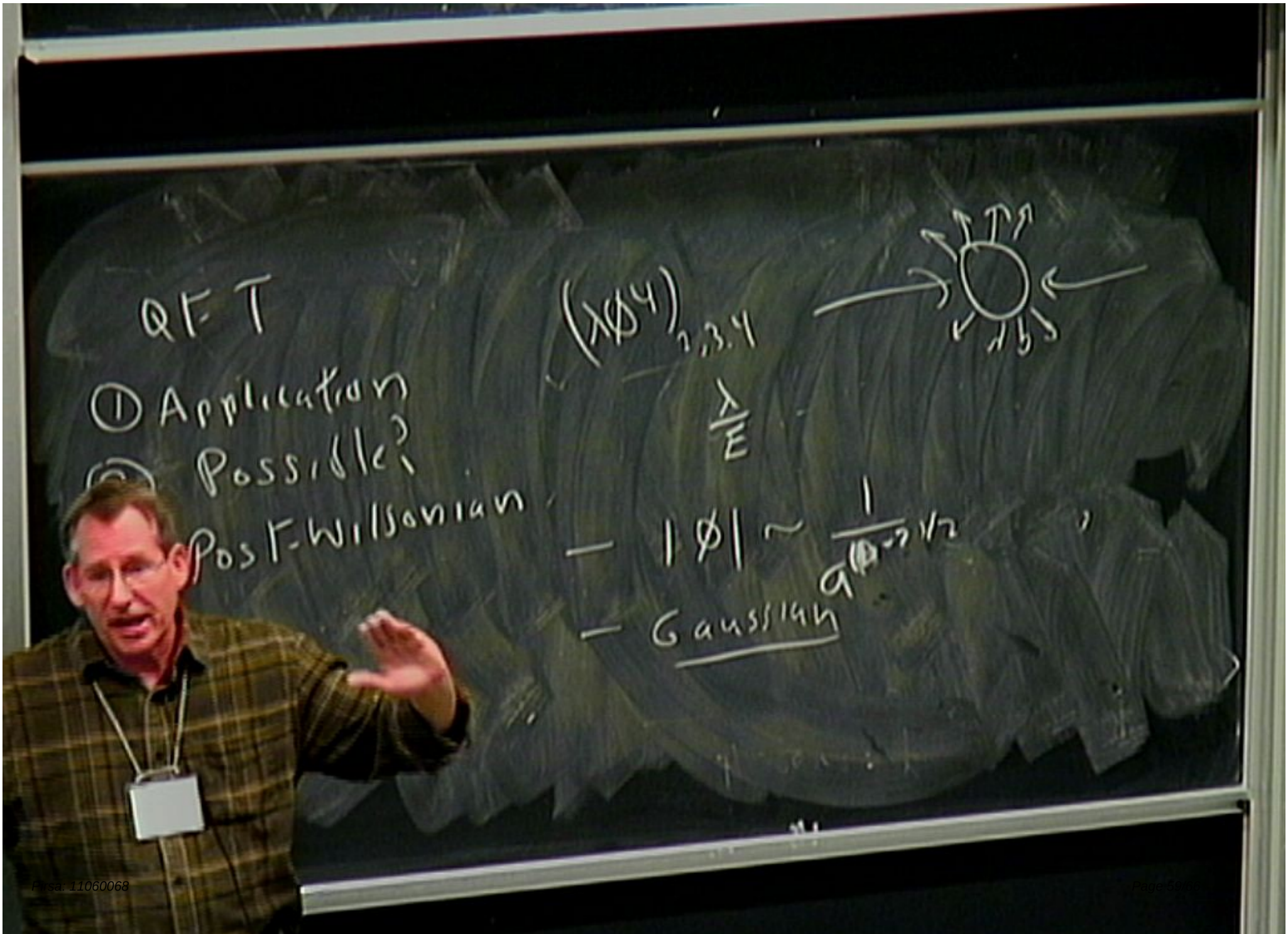
② Possible?

③ Post-Wilsonian

$(\lambda\phi^4)_{2,3,4}$

$\frac{\lambda}{E}$

$|\phi| \sim \frac{1}{a^{(d-2)/2}}$


QFT
(λφ4)2,3,4
λ/E
① Application
Possible?
Post-Wilsonian
— |φ| ~ 1/a(d-2)/2
— Gaussian

QFT

① Application

② Possible?

③ Post-Wilsonian

$(\lambda\phi^4)_{2,3,4}$

$\frac{\lambda}{E}$

— $|\phi| \sim \frac{1}{a^{(d-2)/2}}$

— Gaussian

— Wavepacket

QFT

① Application

② Possible?

③ Post-Wilsonian

$(\lambda\phi^4)_{2,3,4}$

$\frac{\lambda}{E}$

— $|\phi| \sim \frac{1}{a^{(D-2)/2}}$

— Gaussian

— Wavepacket

— $0 \rightsquigarrow \lambda$

$|\lambda|$, $|\lambda|$

QFT

① Application

② Possible?

③ Post-Wilsonian

$\lambda \rightsquigarrow 0$

$(\lambda\phi^4)_{2,3,4}$

$\frac{\lambda}{E}$

- $|\phi| \sim \frac{1}{a^{(d-2)/2}}$
- Gaussian
- Wavepacket
- Evolve

- $0 \rightsquigarrow \lambda$

$|\lambda|$ $|\lambda|$

QFT

$(\lambda\phi^4)_{2,3,4}$

① Application

② Possible?

③ Post-Wilsonian

$\lambda \rightsquigarrow 0$

$\frac{\lambda}{E}$

- $0 \rightsquigarrow \lambda$

$|\phi| \sim \frac{1}{a^{(d-2)/2}}$

Measure modes

- Gaussian
- Wavepacket
- Evolve

QFT

$(\lambda\phi^4)_{2,3,4}$

① Application

② Possible?

③ Post-Wilsonian

$\lambda \rightsquigarrow 0$

$m^2 > 0$ $\quad \frac{\lambda}{E}$

Measure modes

- $|\phi| \sim \frac{1}{a^{(d-2)/2}}$
- Gaussian
- Wavepacket
- Evolve

QFT

$(\lambda\phi^4)_{2,3,4}$

① Application

② Possible? $m^2 > 0$ $\frac{\lambda}{E}$

③ Post-Wilsonian

$\lambda \rightsquigarrow 0$

Measure modes

- $|\phi| \sim \frac{1}{a^{(d-2)/2}}$
- Gaussian
- Wavepacket
- Evolve

- $0 \rightsquigarrow \lambda$

$|\lambda|$, $|\lambda|$

QFT

$(\lambda\phi^4)_{2,3,4}$

① Application

② Possible? $m^2 > 0$ $\frac{\lambda}{E}$

③ Post-Wilsonian

$\lambda \rightsquigarrow 0$

Measure modes

- $|\phi| \sim \frac{1}{a^{(D-2)/2}}$
- Gaussian
- Wavepacket
- Evolve

$\left(\frac{Vt}{a^D}\right)^{1+\varepsilon}$

- $0 \rightsquigarrow \lambda$

$|\Lambda|$, $|\Lambda|$