Title: Bounce in Loop Quantum Cosmology and its Implications

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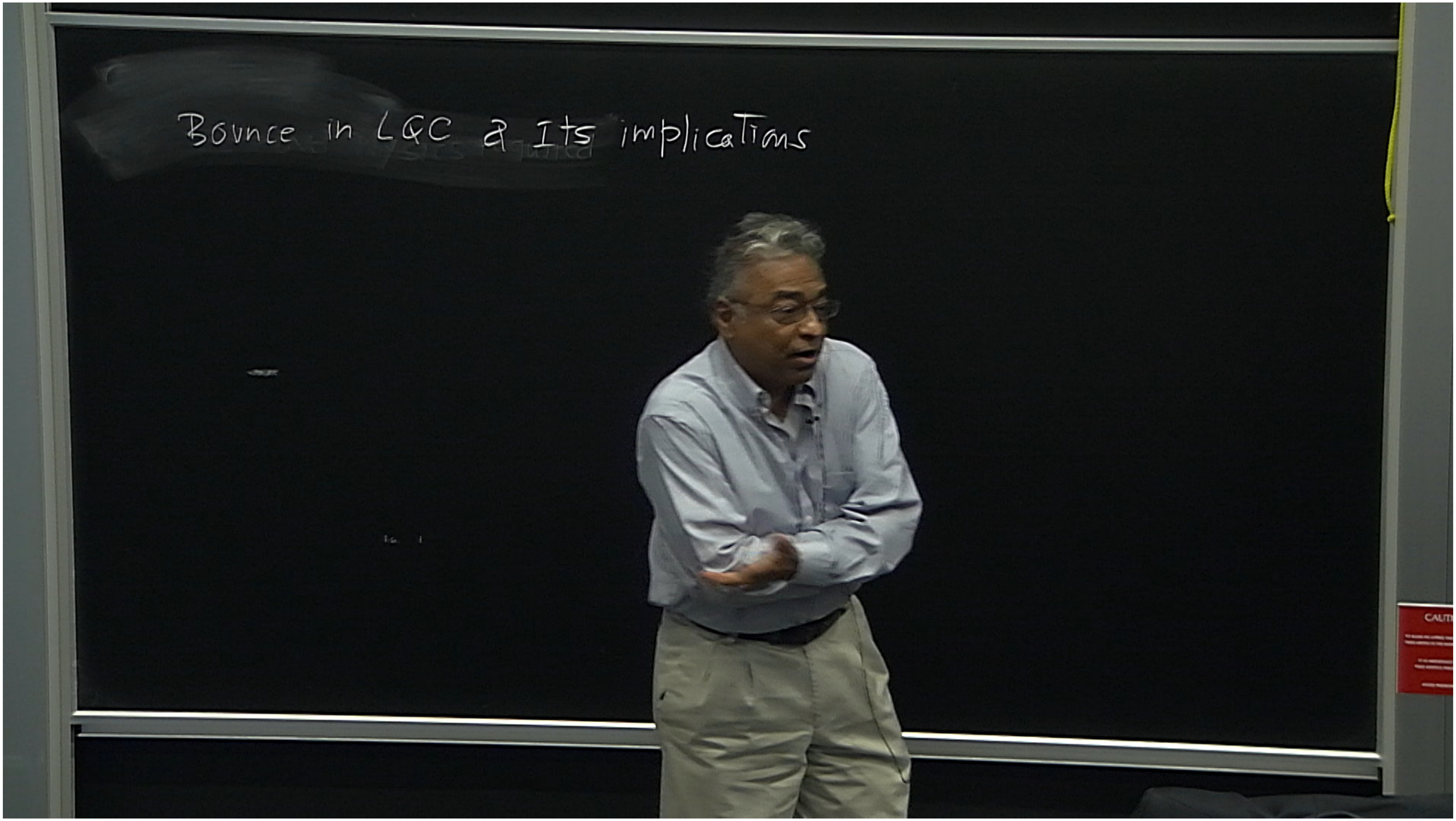
URL: http://pirsa.org/17060095

Abstract: There is a huge body of work in Loop Quantum Cosmology comprising of several thousand journal articles. I will provide an overview of conclusions, focusing on the difficult conceptual and mathematical issues that accompany the notion of a bounce and opening the way for phenomenological implications that will be discussed by Ivan Agullo.


Bounce in LQC & Its implications

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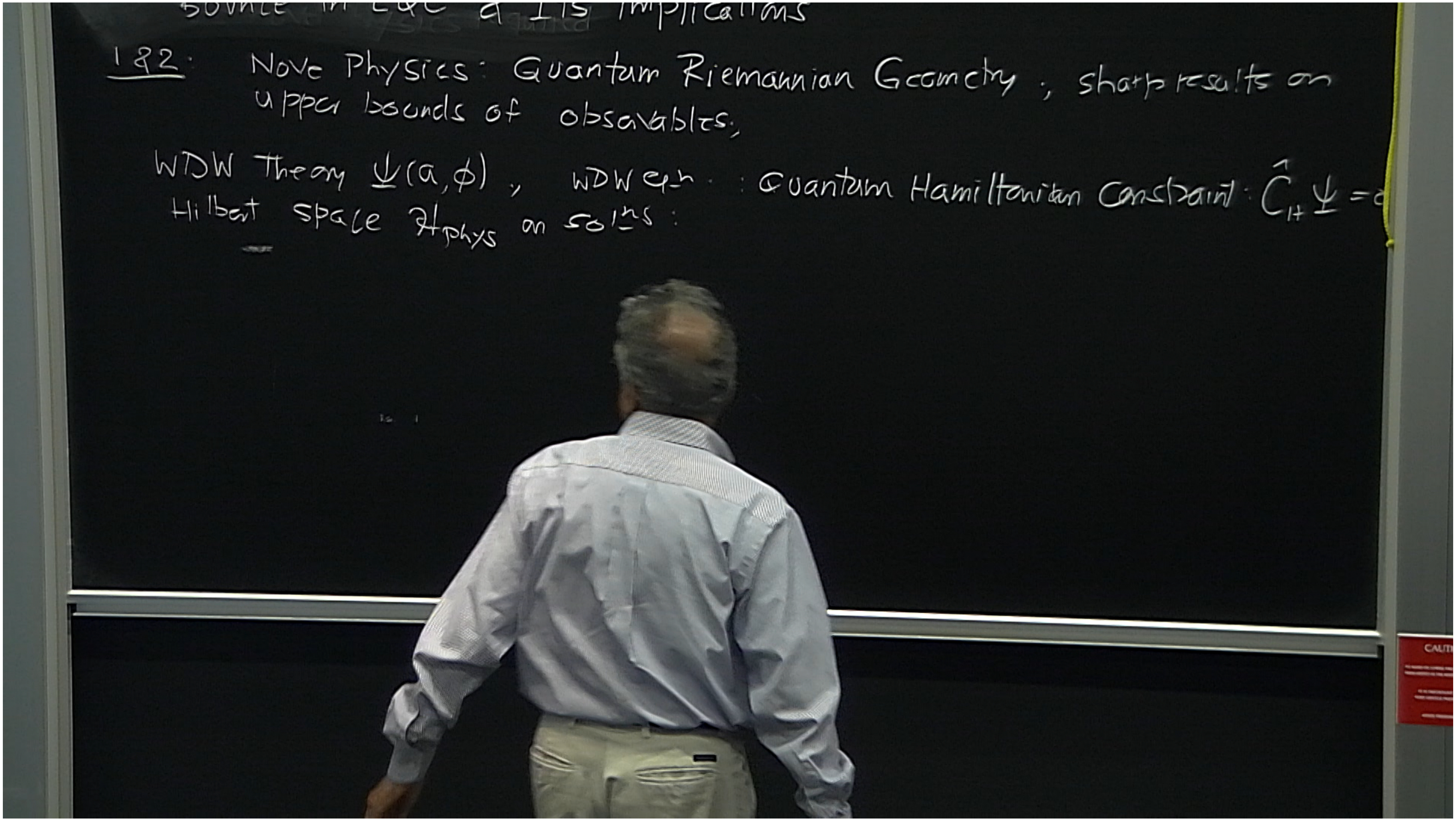
1&2: Novel Physics: Quantum Riemannian Geometry

Bounce in LQC & Its implications

1 & 2: Novel Physics: Quantum Riemannian Geometry; sharp results on upper bounds of observables;

WDW Theory $\Psi(a,\phi)$, WDW eq^n: Quantum Hamiltonian Constraint: $\hat{C}_H \Psi = 0$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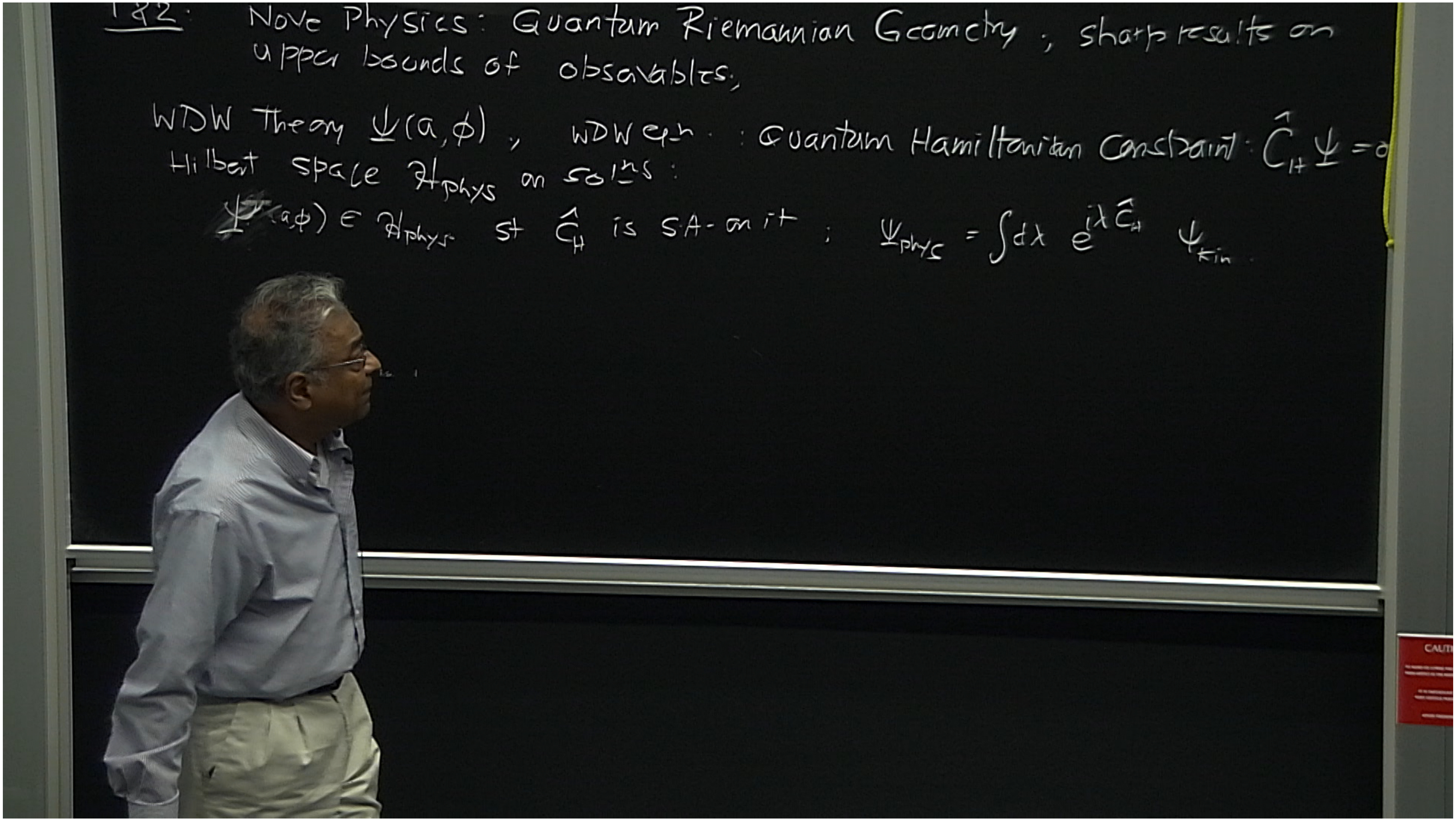
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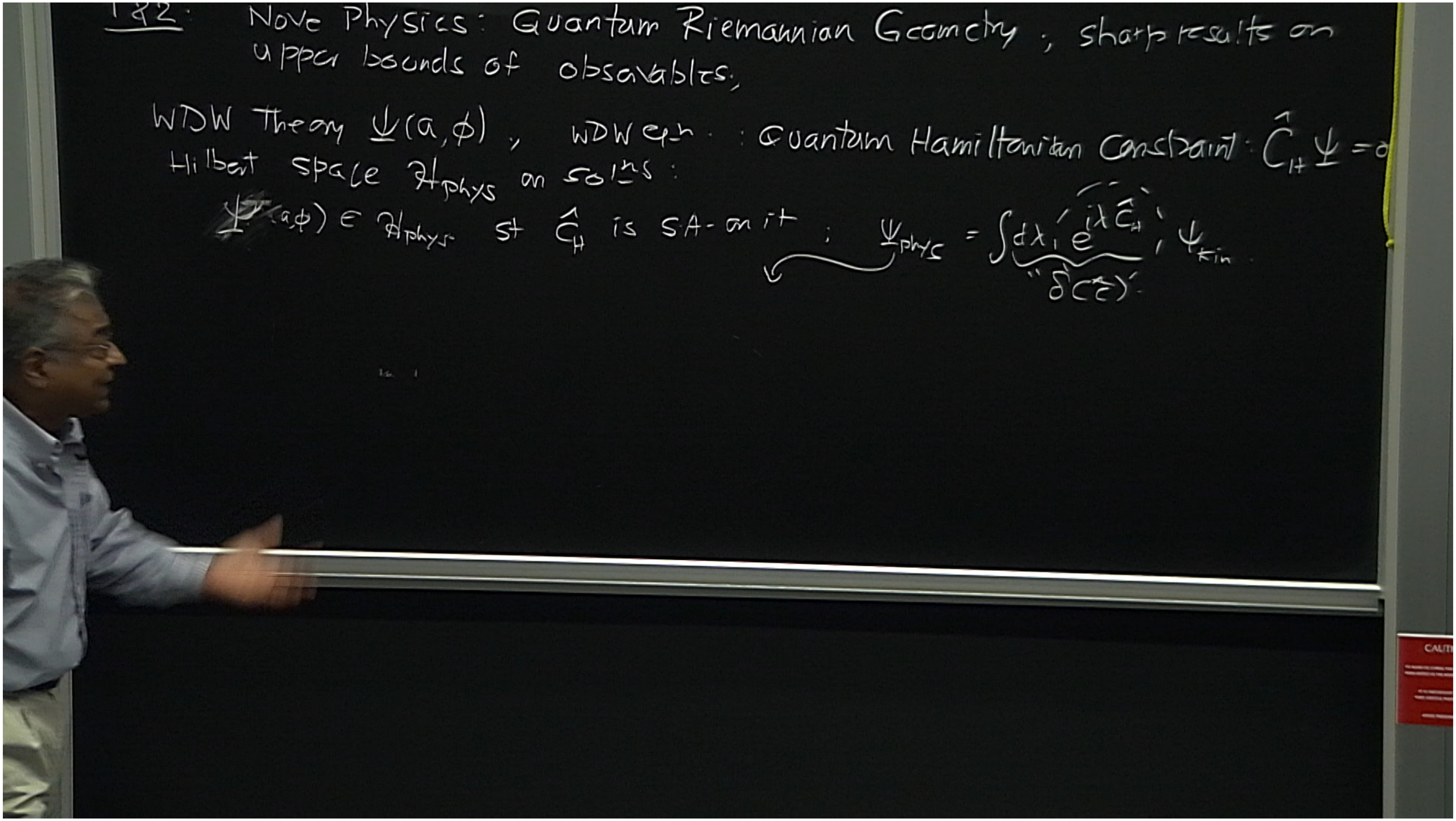
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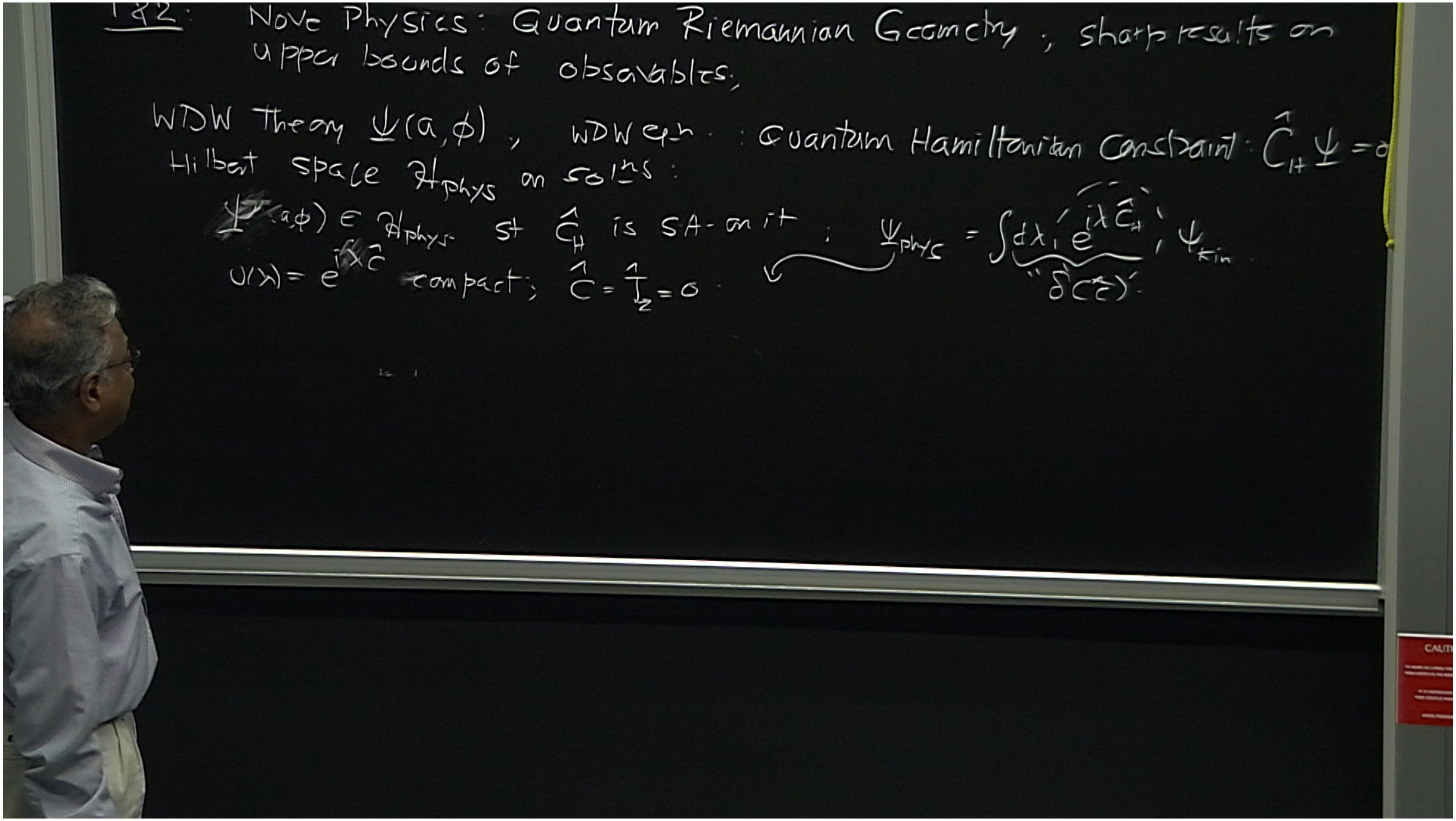
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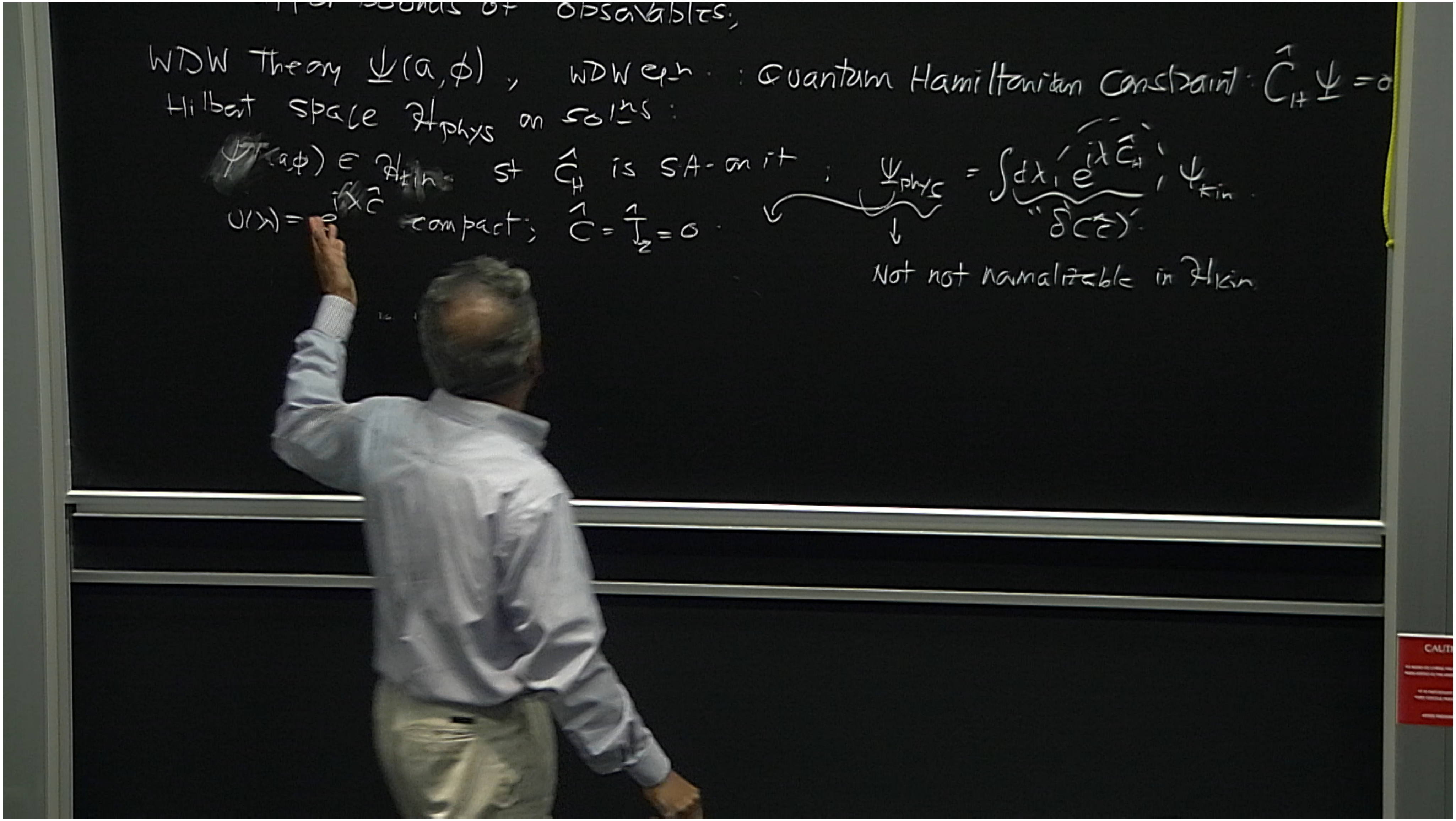
bounds of observables;
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Not not normalizable in H_kin

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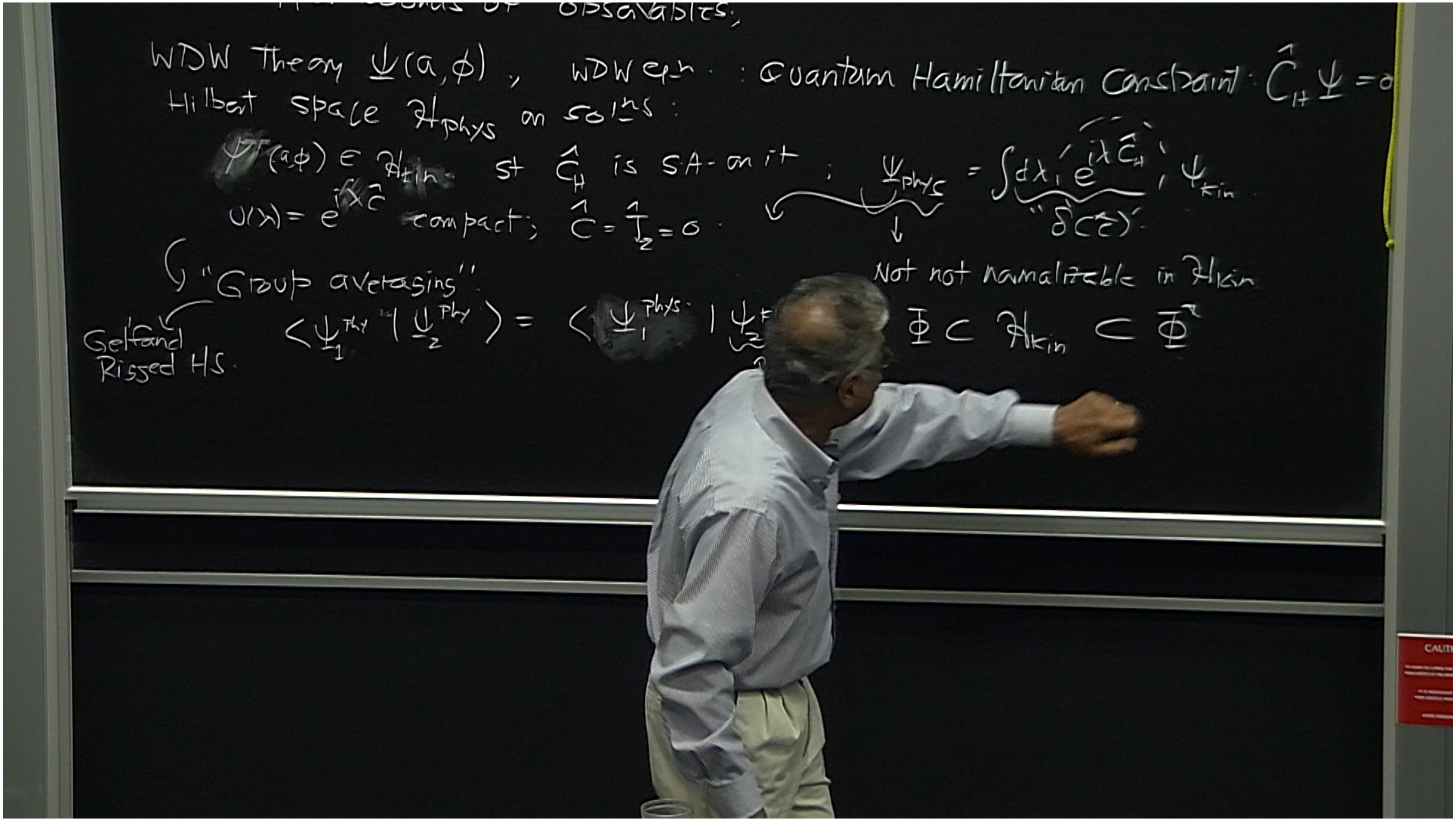
↳ "Group averaging"

Not normalizable in $\mathcal{H}_{kin}$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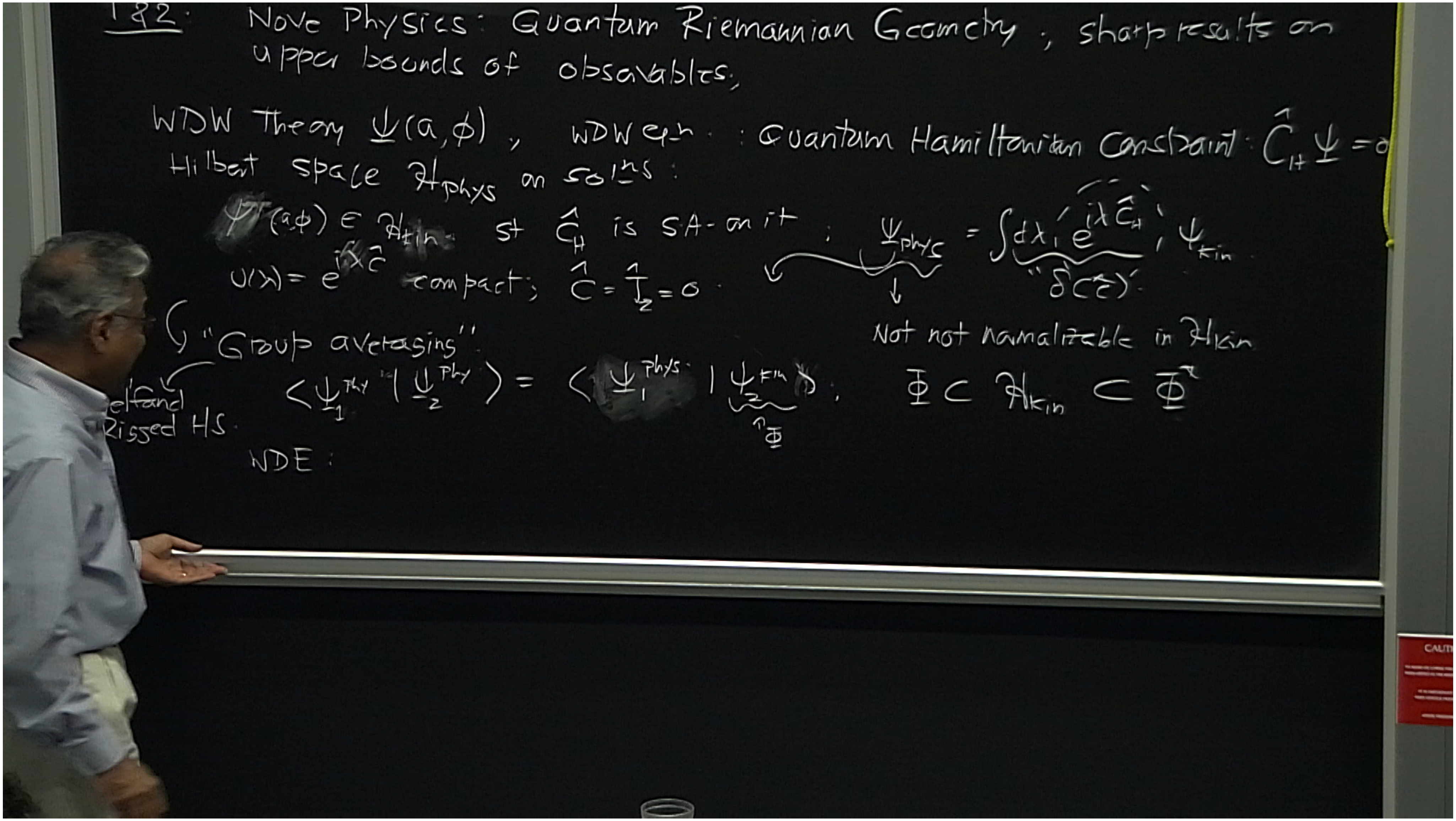
"Group averaging" Not not normalizable in $\mathcal{H}_{kin}$

Gelfand Rigged HS. $\langle \Psi_1^{phy} | \Psi_2^{phy} \rangle = \langle \Psi_1^{phys} | \Psi_2^{kin} \rangle$; $\Phi \subset \mathcal{H}_{kin} \subset \Phi^*$

$\Psi_2^{kin} \in \Phi$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matter

WDE : Scalar field ϕ $(m=0)$.

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$\Psi_{phy}(a,\phi)$

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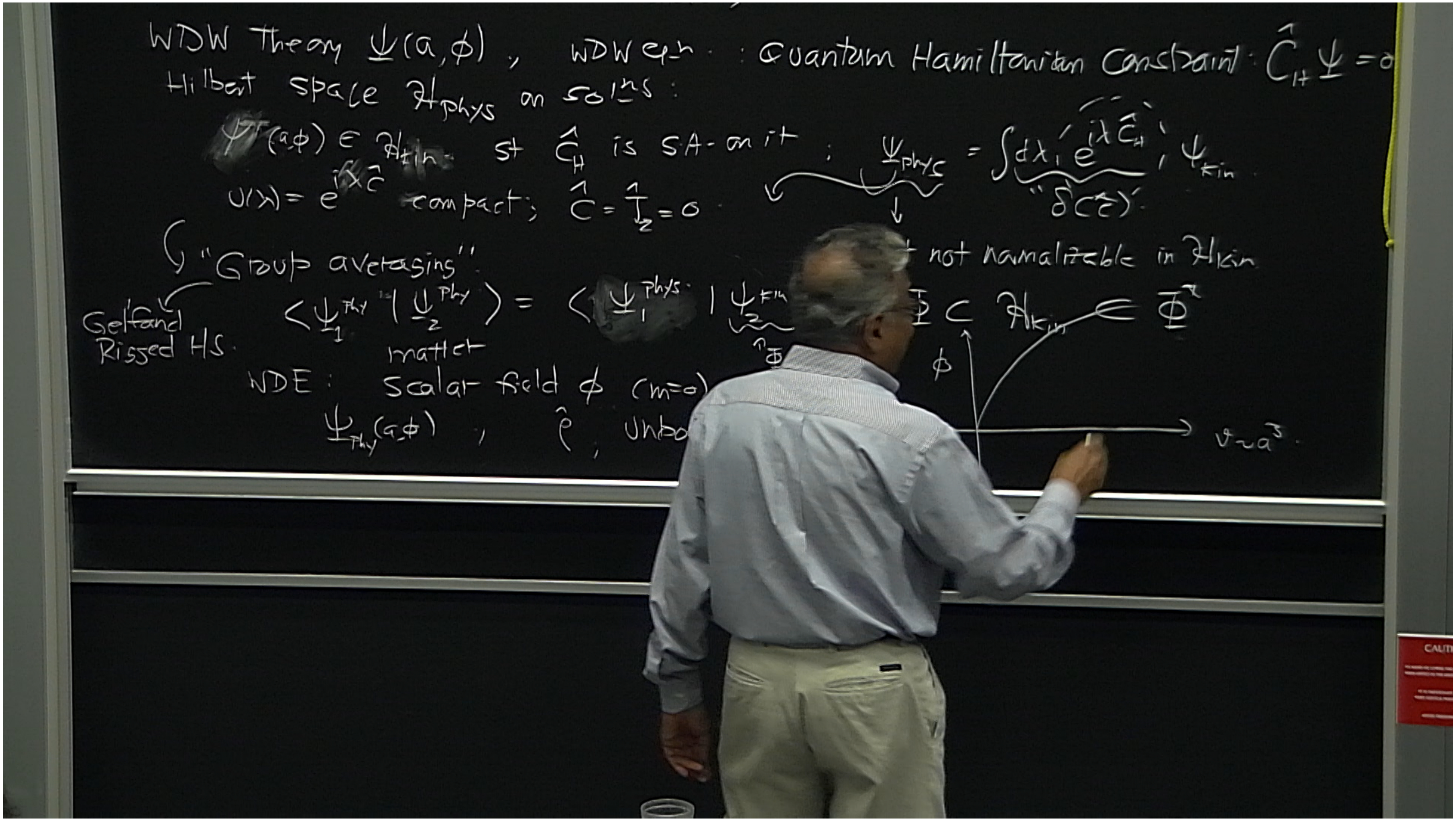
$\Psi_{phy}(a,\phi)$, $\hat{\rho}$,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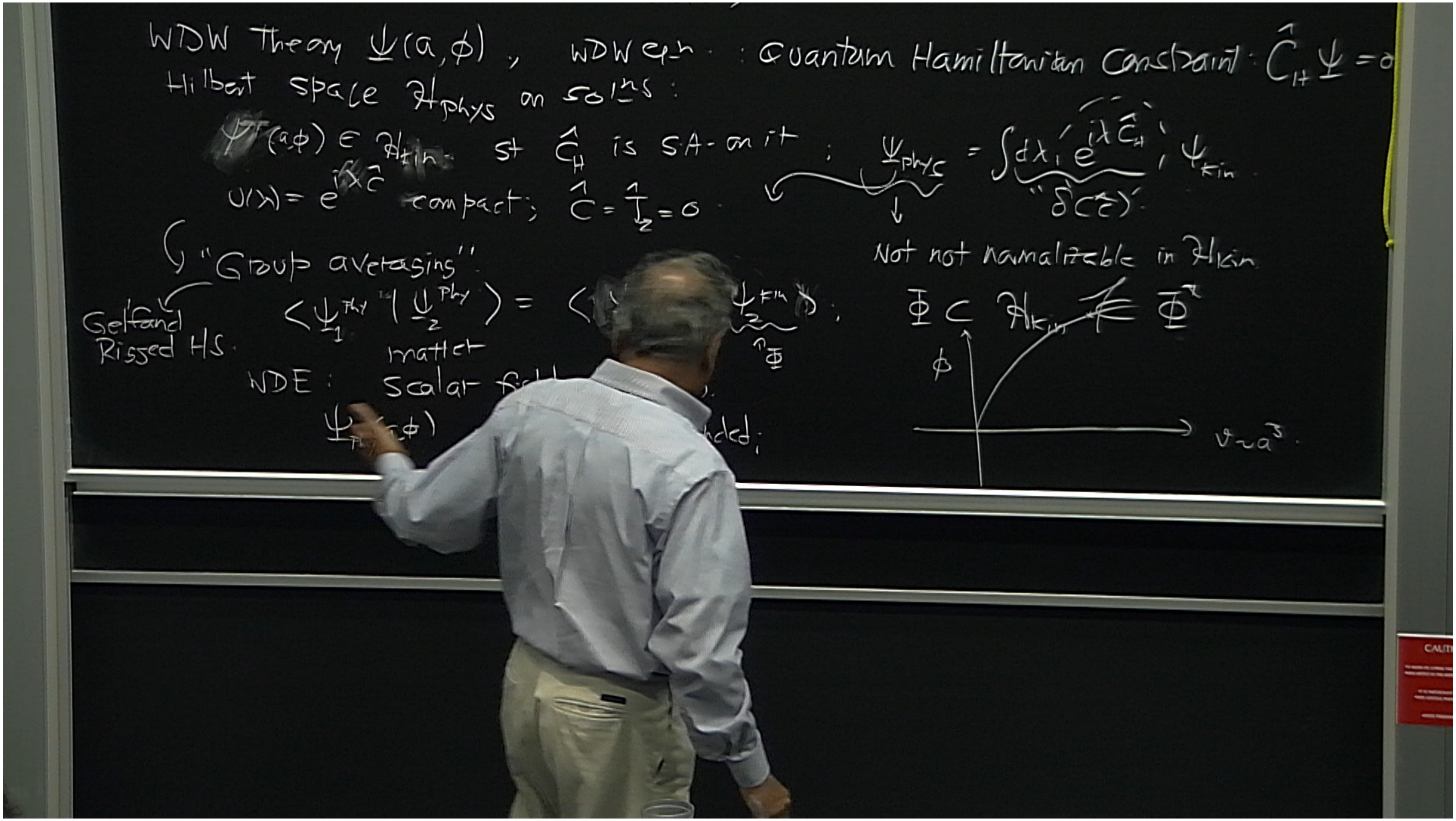
$\Psi_{phy}(a,\phi)$, $\hat{p}$, unbo
ϕ
$v \sim a^3$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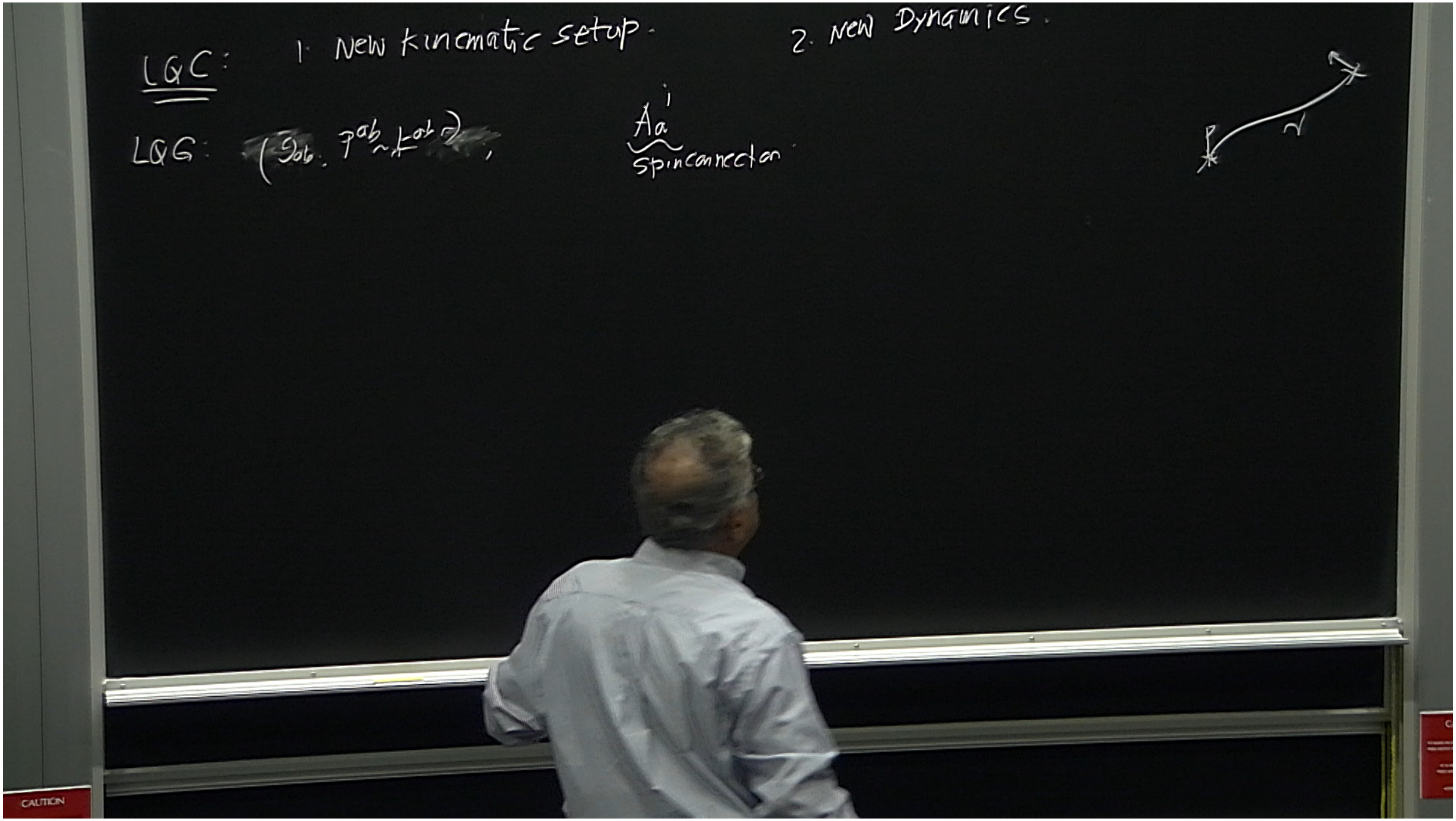
φ
v ~ a^3

LQC:

1. New kinematic setup.
2. New Dynamics.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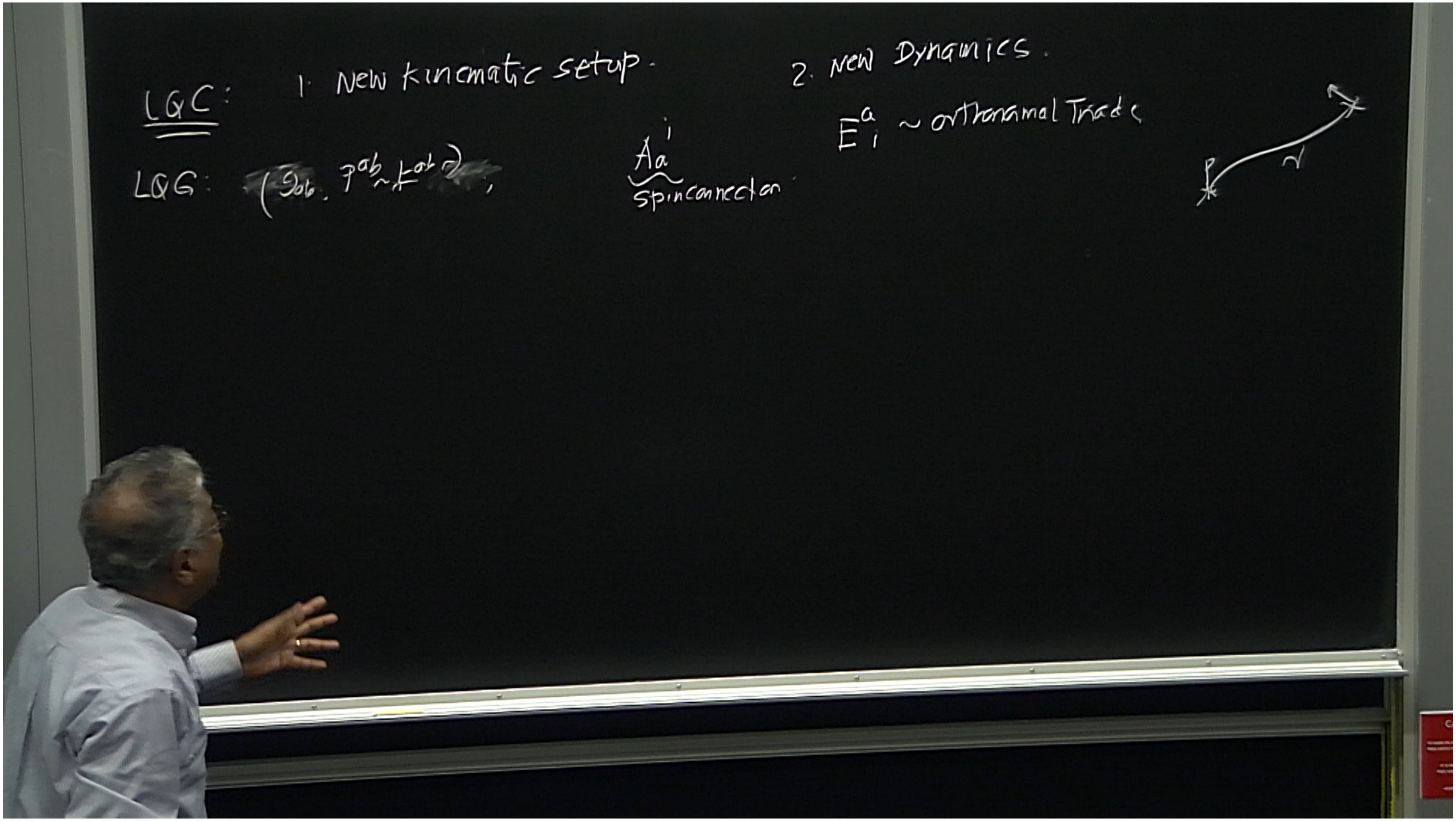
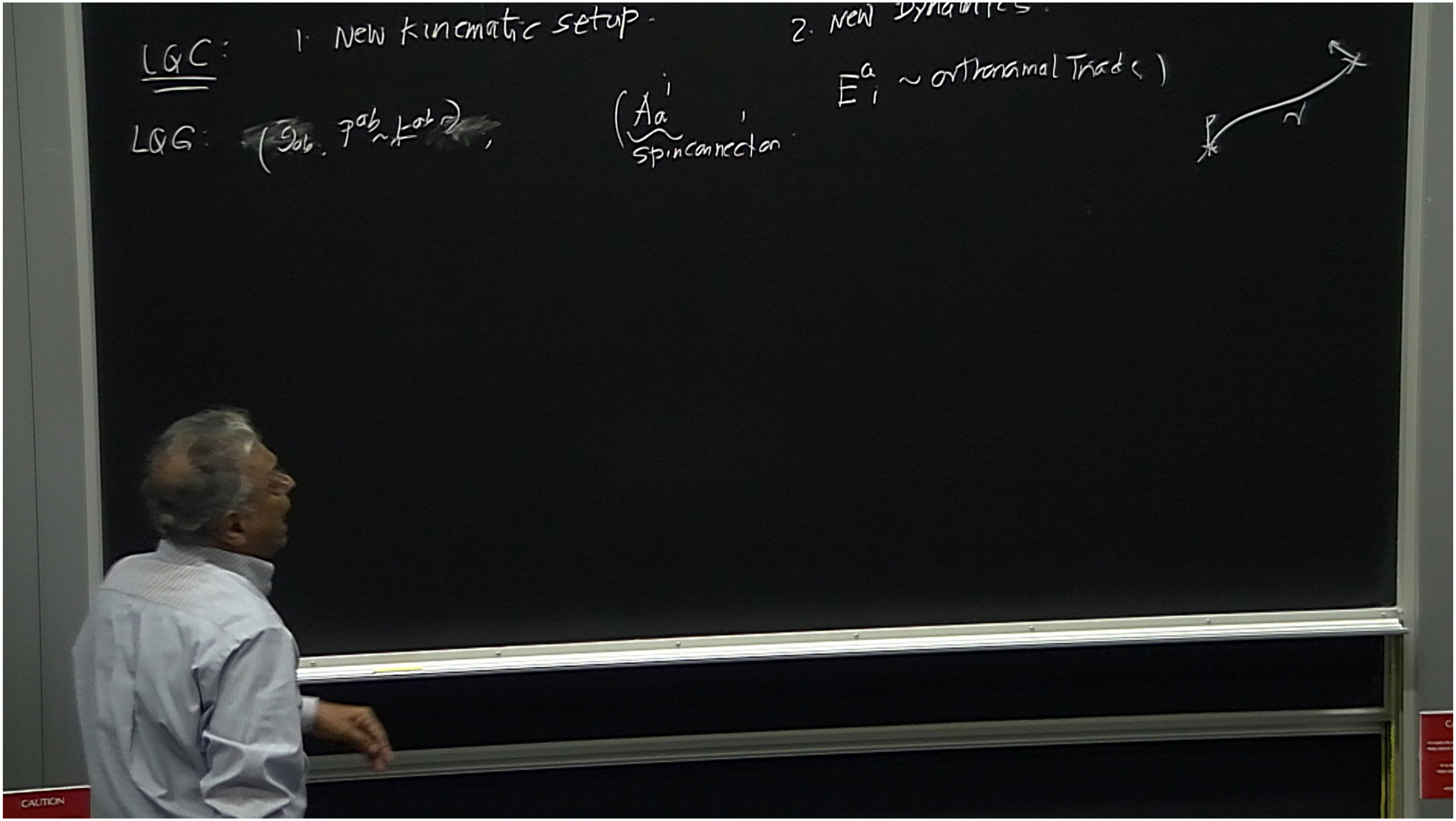
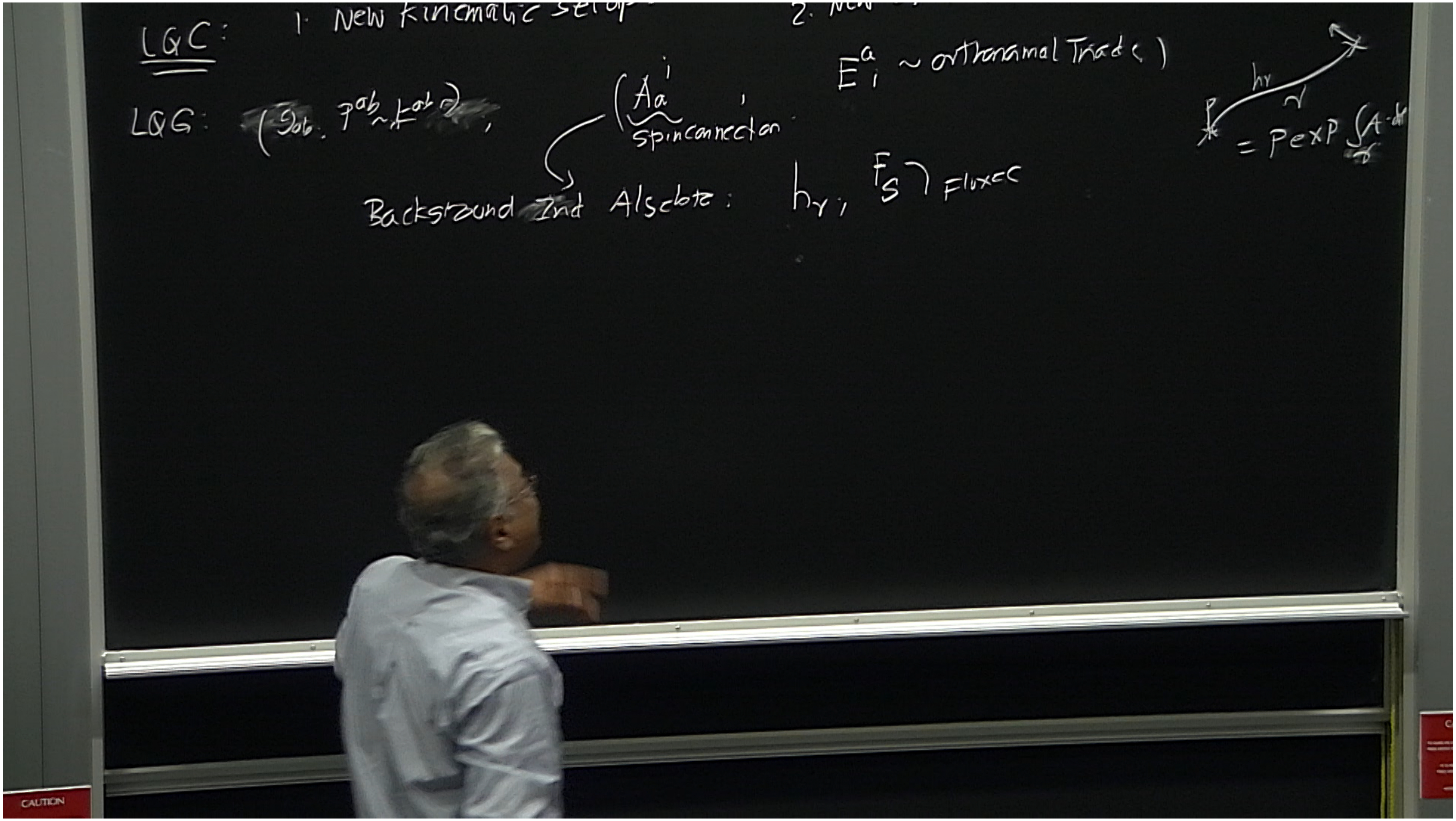
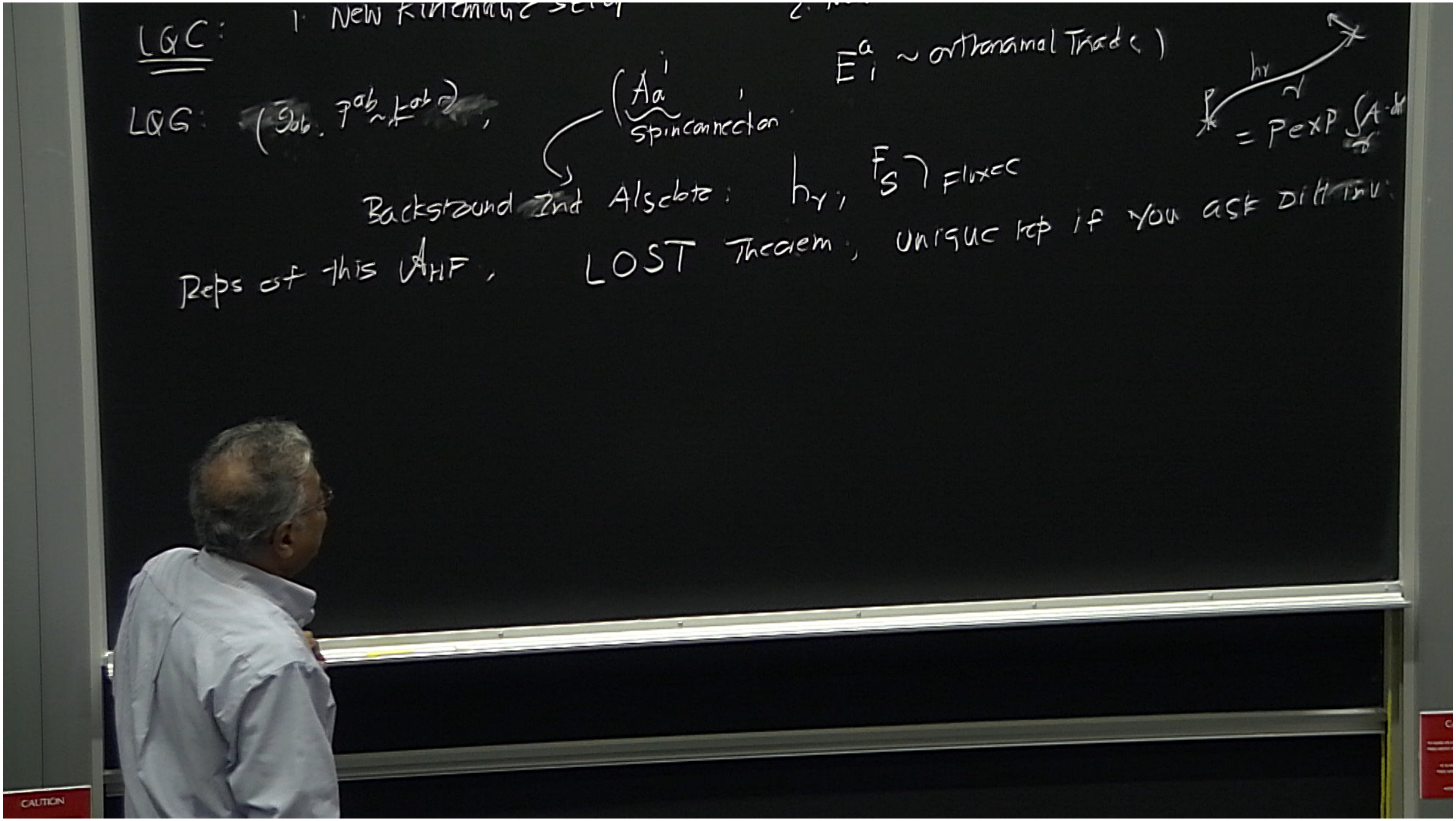
LQG:
A_a^i
spin connection


LQC: 1. New kinematic setup. 2. New Dynamics.
LQG: (g_{ab}, p^{ab} ~ K^{ab})
A_a^i spinconnection
E^a_i ~ orthonormal Triads
p
γ


LQC: 1. New kinematic setup. 2. New Dynamics.
LQG:
spinconnection
orthonormal Triad
CAUTION


LQC: 1. New kinematic
2. New
LQG:
E ~ orthonormal Triads
spinconnection
Background Ind Algebra: h, F, Fluxes
= P exp
CAUTION


LQC: 1. New kinematic
LQG: (gab, pab ~ Kab),
(Aa spinconnection, Ei ~ orthonormal Triad)
= P exp ∫ A·dl
Background Ind Algebra: hγ, FS Fluxes
Unique Rep if you ask Diff Inv.
Reps of this AHF, LOST Theorem

LQC: 1. New Kinematic ...

LQG: $(g_{ab},\ p^{ab} \sim K^{ab})$, $\quad (\underbrace{A_a^i}_{\text{spin connection}},\ E^a_i \sim \text{orthonormal Triads})$

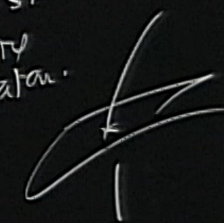
Background Ind Algebra: h_γ, F_S } Fluxes

h_γ, γ, p $= P\exp \int_\gamma A \cdot dl$

Reps of this $\mathcal{A}_{HF}$, LOST Theorem, Unique Rep if you ask Diff inv.

elementary excitation.

→ Riem Geo observables: Discrete eigenvalues.



LQC: 1. New kinematic setup. 2. New Dynamics.

$E^a_i \sim$ orthonormal Triads)

LQG: $(g_{ab}, p^{ab} \sim K^{ab})$, $(\underbrace{A_a^i}_{\text{spin connection}}, \quad)$

$\int_\alpha \quad S_{p(\alpha)}$

Background Ind Algebra: h_γ, F_S } Fluxes

$h_\gamma \sim = P\exp \int_\gamma A\cdot dl$

{ Reps of this $\mathcal{A}_{HF}$, LOST Theorem, unique rep if you ask Diff inv: elementary excitation.

→ Riem Geo observables: Discrete eigenvalues.

LQC: $A_a^i \sim c\, \mathring{e}_a^i$, $E^a_i \sim p_{(c)}$

with an eye to the full theory.

LQC: 1. New kinematic setup. 2. New Dynamics.

$E^a_i \sim$ orthonormal Triad(s)

LQG: $(g_{ab}, \; p^{ab} \sim K^{ab})$, $\;\big(\underbrace{A^i_a}_{\text{spinconnection}}$, $E^a_i\big)$

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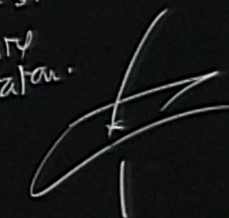


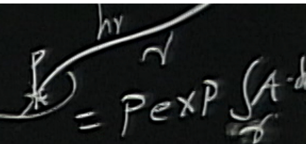
LQC: $A^i_a \sim c\, \underbrace{\mathring{e}^i_a}$, $E^a_i \sim p_{(c)}$ Observables: $h_\gamma \sim e^{i\mu c}\big|_{\mathbb{R}}$ Fluxes ~ p

with an eye to the full theory.

LQG: $(g_{ab}, \pi^{ab} \sim K^{ab})$, $(A_a^i$, $E^a_i)$

$\underbrace{A_a}_{\text{spinconnection}}$

Background Ind Algebra: h_γ, F_S } Fluxes



$= P\exp \int_\gamma A \cdot dx$

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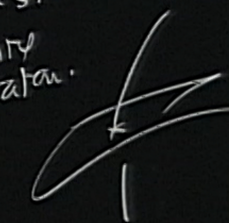

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With an eye to the full theory.

Unique rep: $\psi(c)$ not $L^2(\mathbb{R})$

LQC:

$E^a_i \sim$ orthonormal Triad ( )

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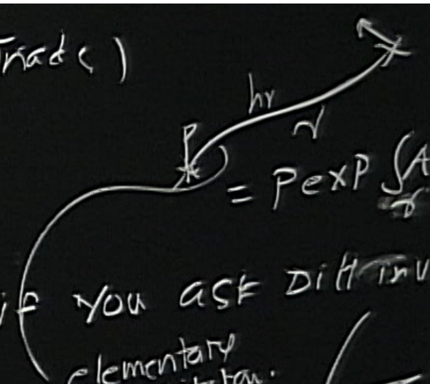
Background Ind Algebra: h_γ, F_S } Fluxes



$h_\gamma = P\exp \int_\gamma A \cdot dl$

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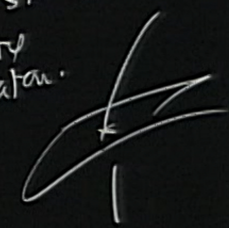

LQC: $A_a^i \sim c\, \overset{o}{e}{}_a^i$, $E^a_i \sim p_{(c)}$

With an eye to the full theory, Observables: $h_\gamma \sim e^{i\mu c}\Big|_{\mathbb{R}}$ Fluxes $\sim p$

Unique rep: $\psi(c)$ not $L^2(\mathbb{R})$ $\qquad \psi(c) = \sum_{j=1}^{N} \alpha_j\, e^{i\mu_j c}$

(Inequivalent to std schrodinger rep,

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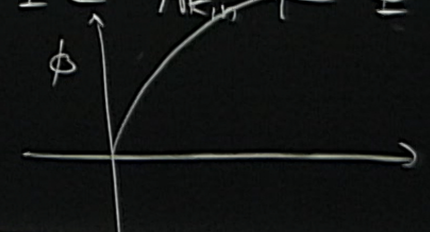
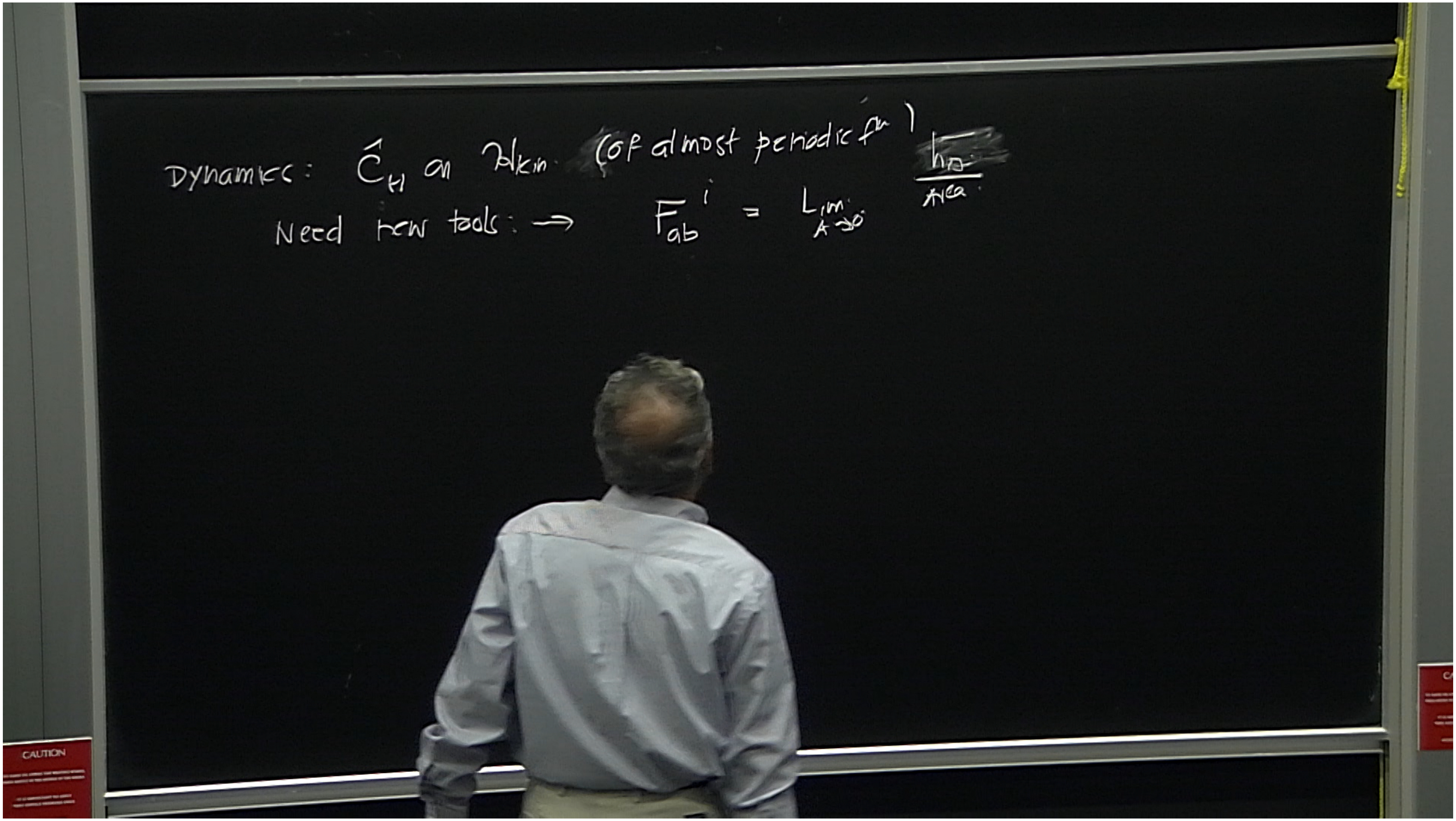
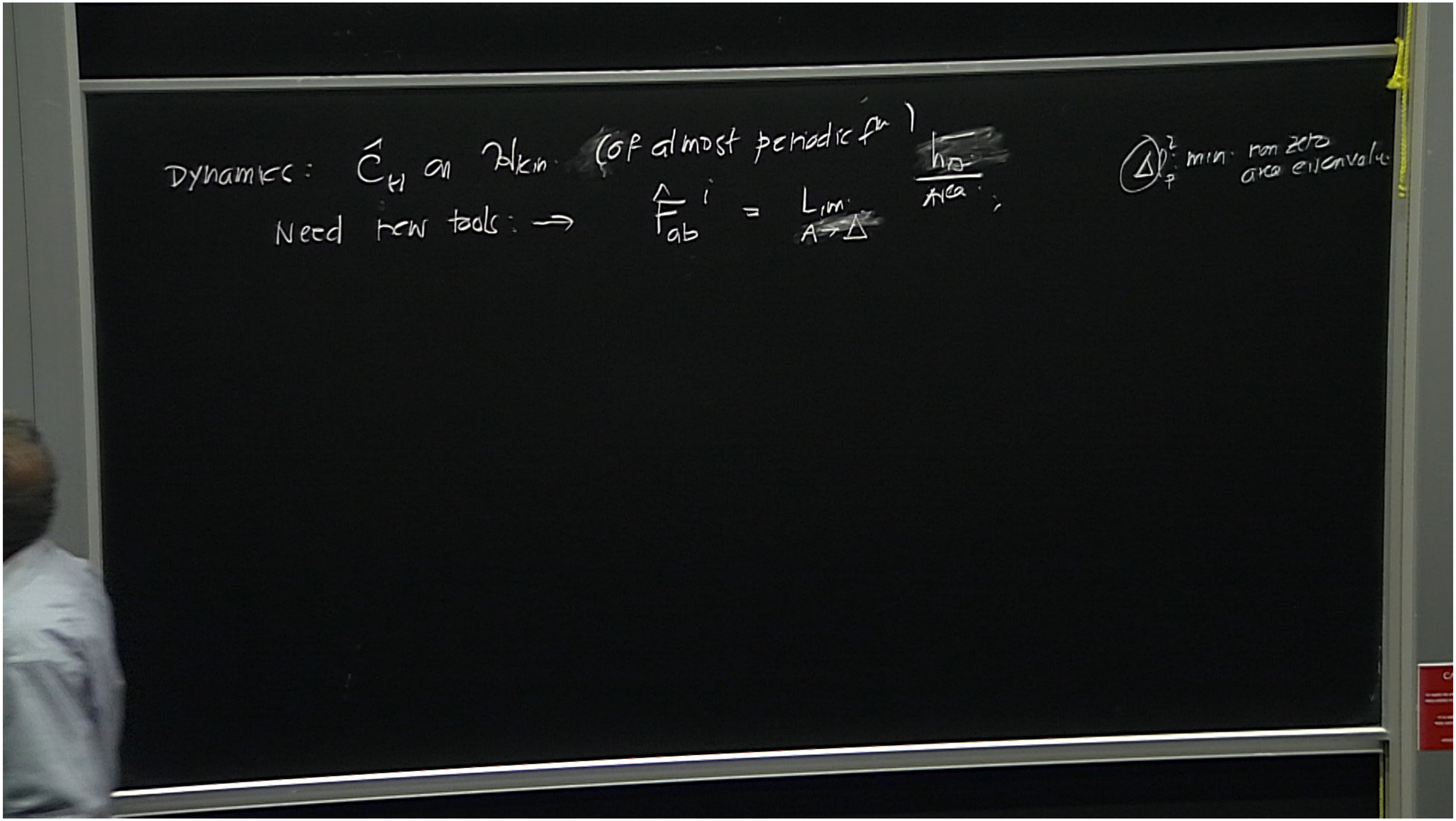
matter

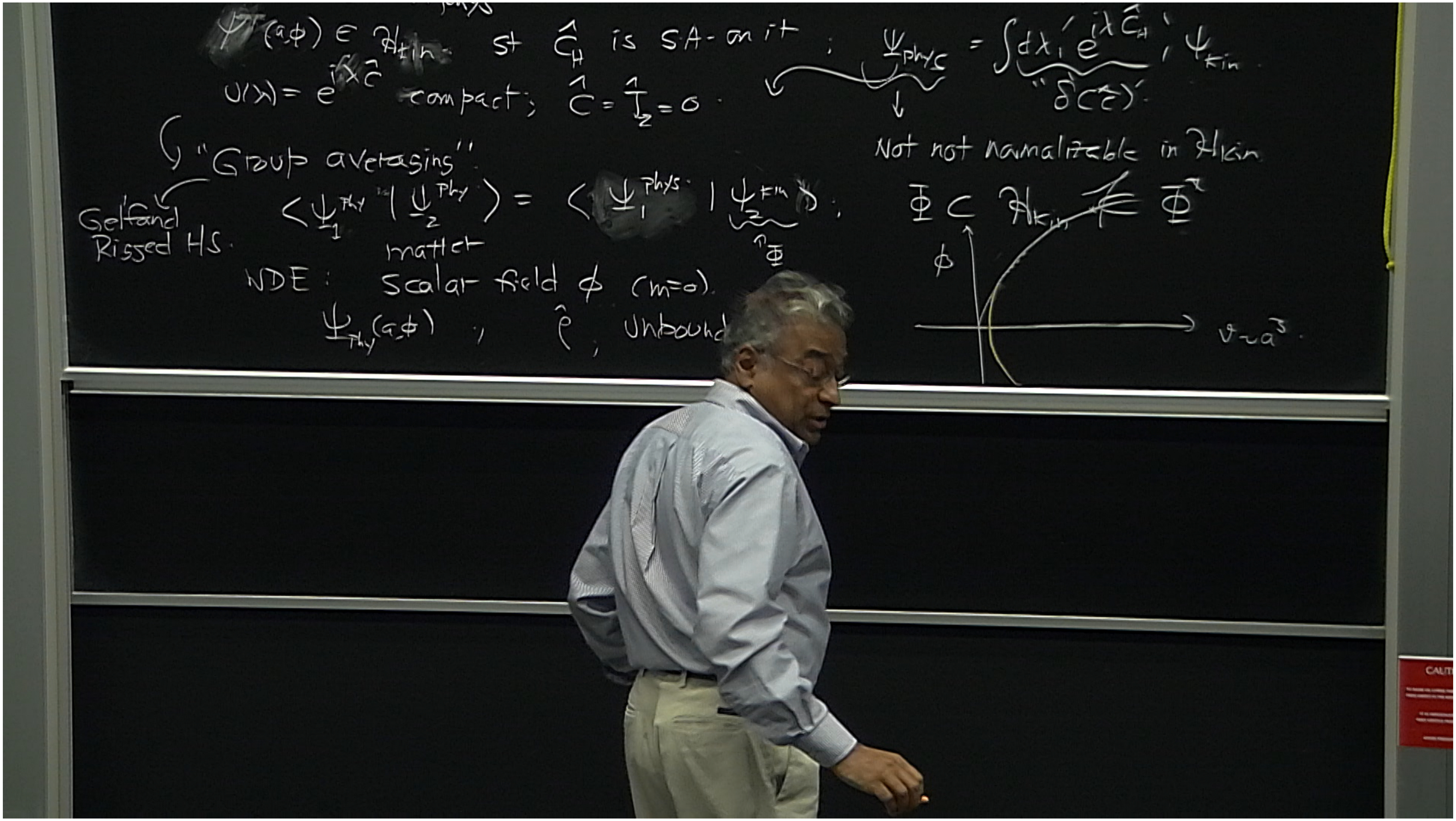
WDE: scalar field ϕ $(m=0)$.

$\Psi_{Phy}(a,\phi)$, $\hat{\rho}$, unbounded.




Dynamics: Ĉ_H on H_kin (of almost periodic fn) h_□ / Area
Need new tools: → F_ab^i = Lim_{A→0}
CAUTION


Dynamics: Ĉ_H on H_kin (of almost periodic fn)
Need new tools: → F̂_ab^i = Lim_{A→Δ} h_□ / Area ;
Δ_P^2: min. non zero area eigenvalue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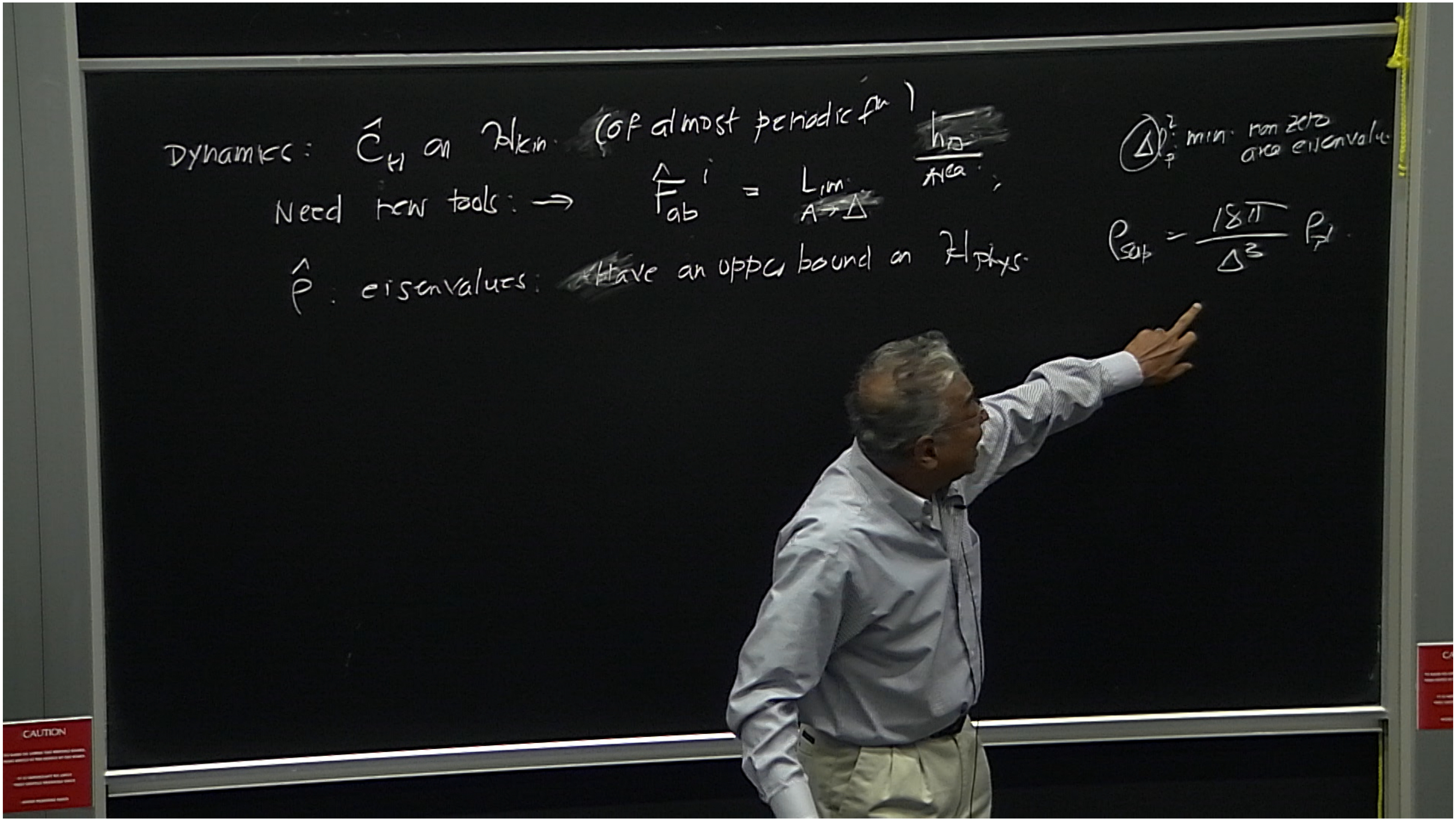
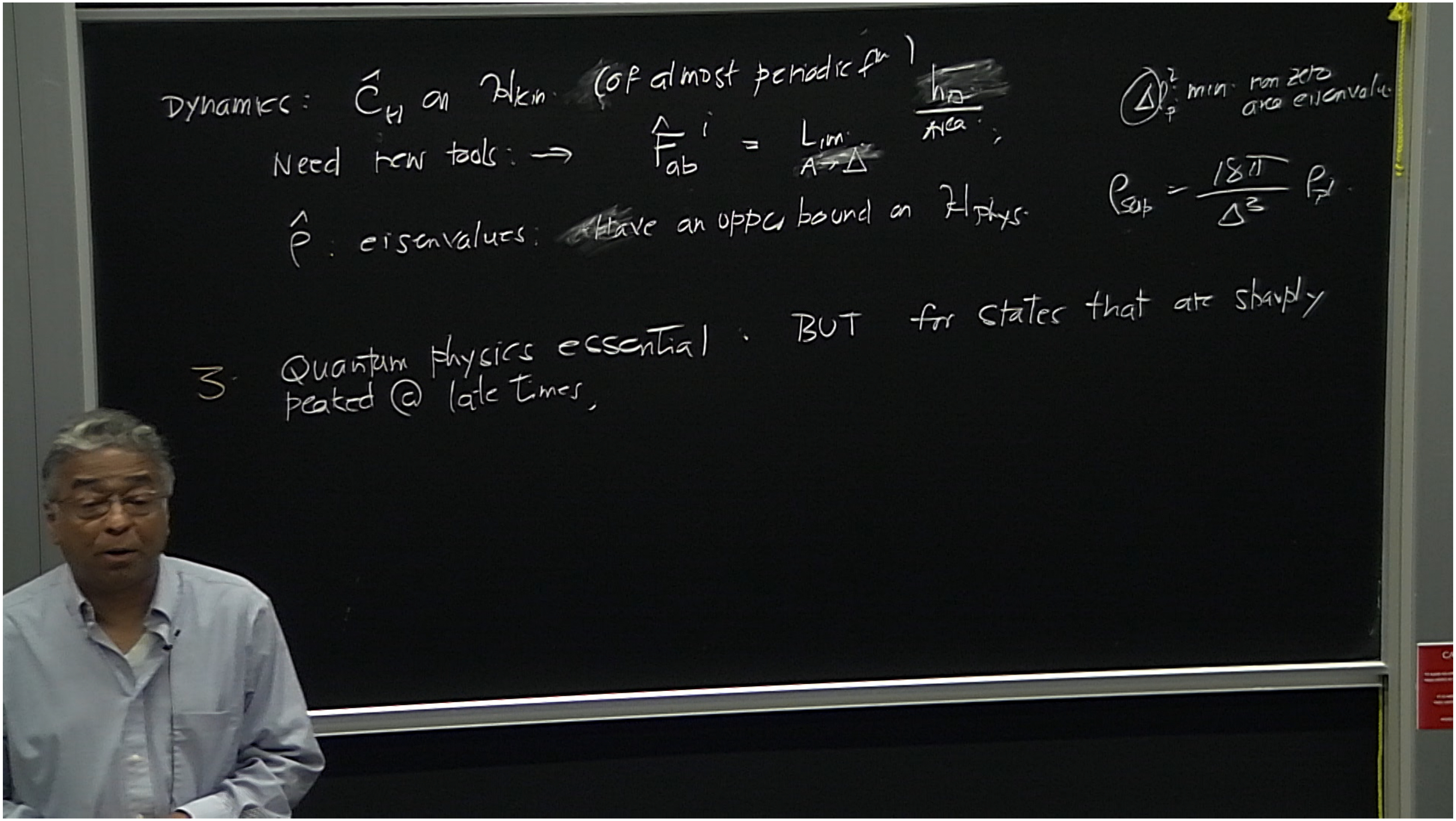
matter
NDE: Scalar field φ (m=0)
Ψ_Phy(a,φ), p̂, Unbound
Ψ_phys = ∫dλ e^{iλĈ_H} Ψ_kin
"δ(Ĉ)"
Not normalizable in H_kin
Φ ⊂ H_kin ⊂ Φ*
φ
v ~ a^3


Dynamics: $\hat{C}_H$ on $\mathcal{H}_{kin}$ (of almost periodic fn)
Need new tools: → $\hat{F}_{ab}{}^i = \lim_{A \to \Delta} \frac{h_\Box}{\text{Area}}$;
$\hat{\rho}$: eigenvalues: Have an upper bound on $\mathcal{H}_{phys}$.
$\Delta \ell_P^2$: min. non zero area eigenvalue
$\rho_{sup} = \frac{18\pi}{\Delta^3} \rho_{Pl}$
CAUTION


Dynamics: $\hat{C}_H$ on $\mathcal{H}_{kin}$ (of almost periodic fn)
Need new tools: → $\hat{F}_{ab}{}^{i} = \lim_{A \to \Delta} \frac{h_{\square}}{Area}$;
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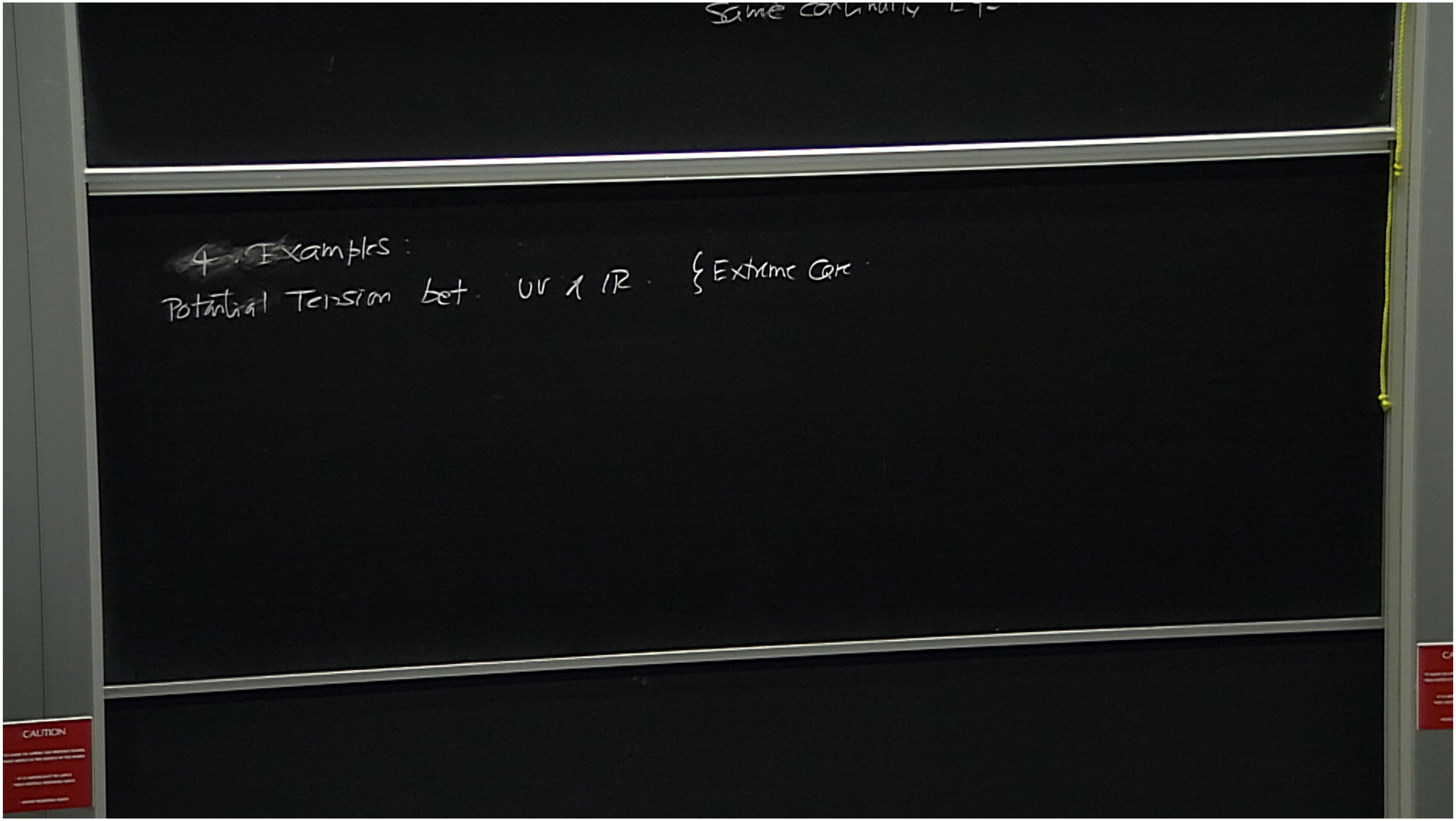
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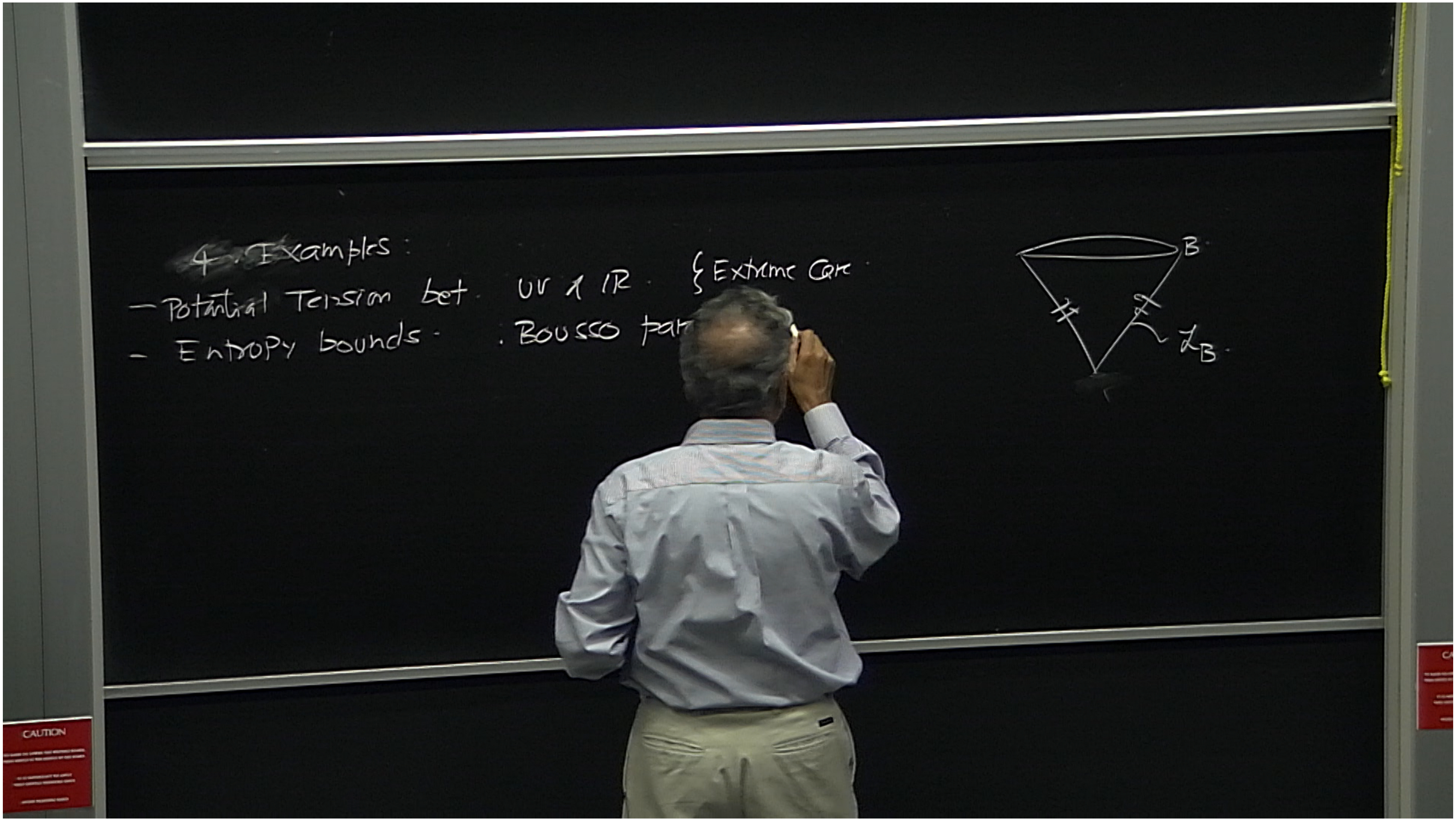
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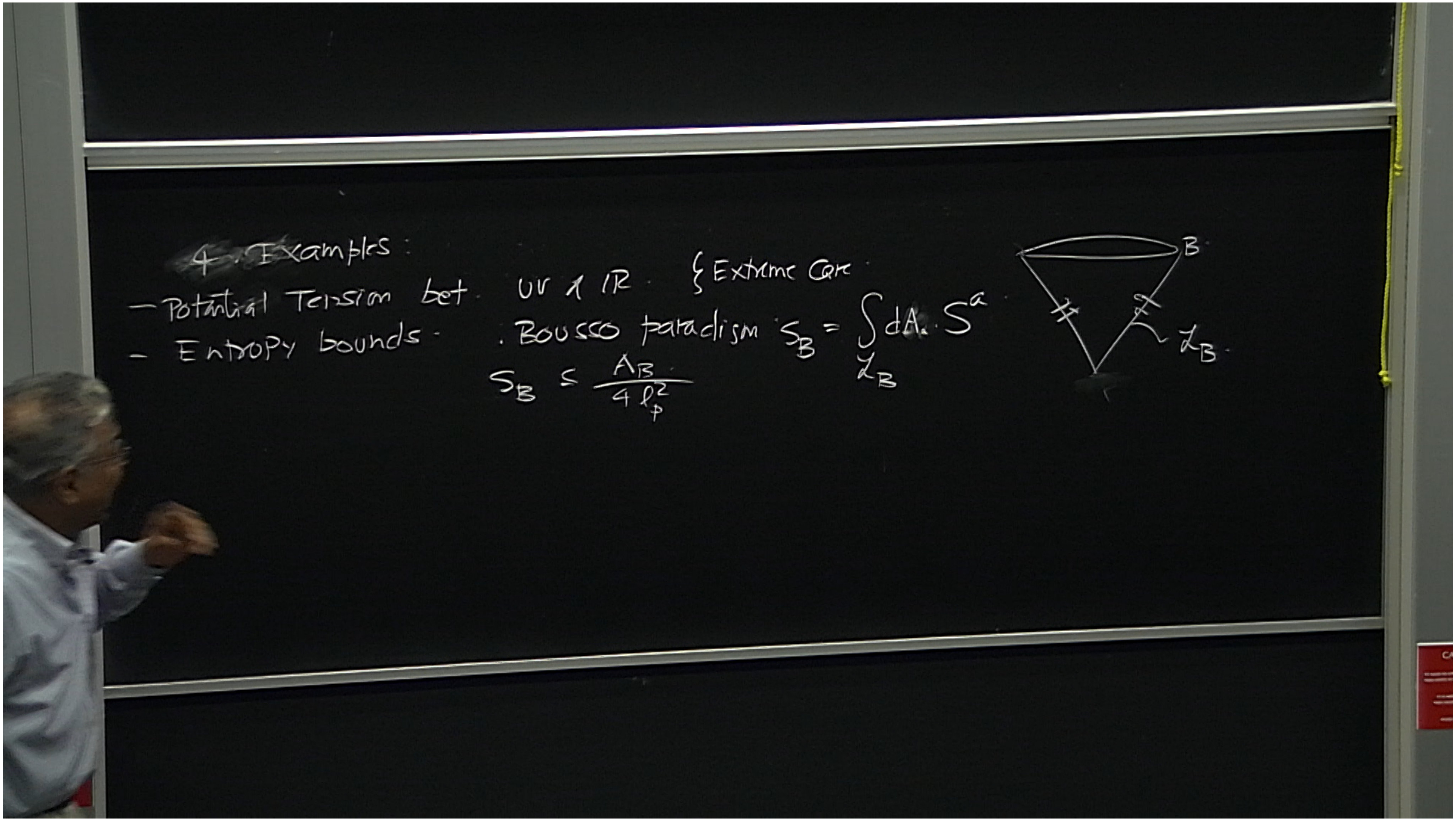
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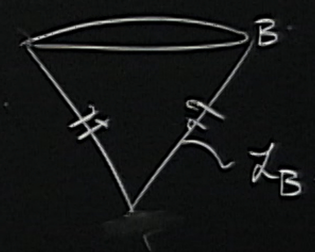

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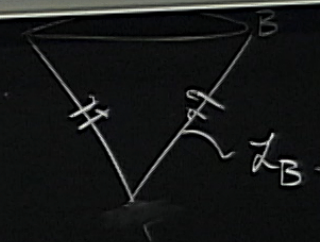

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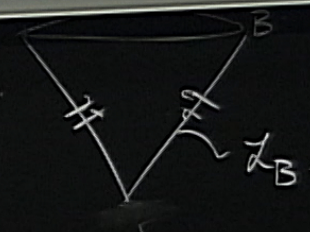

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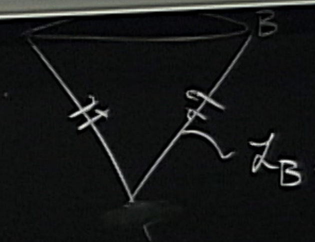

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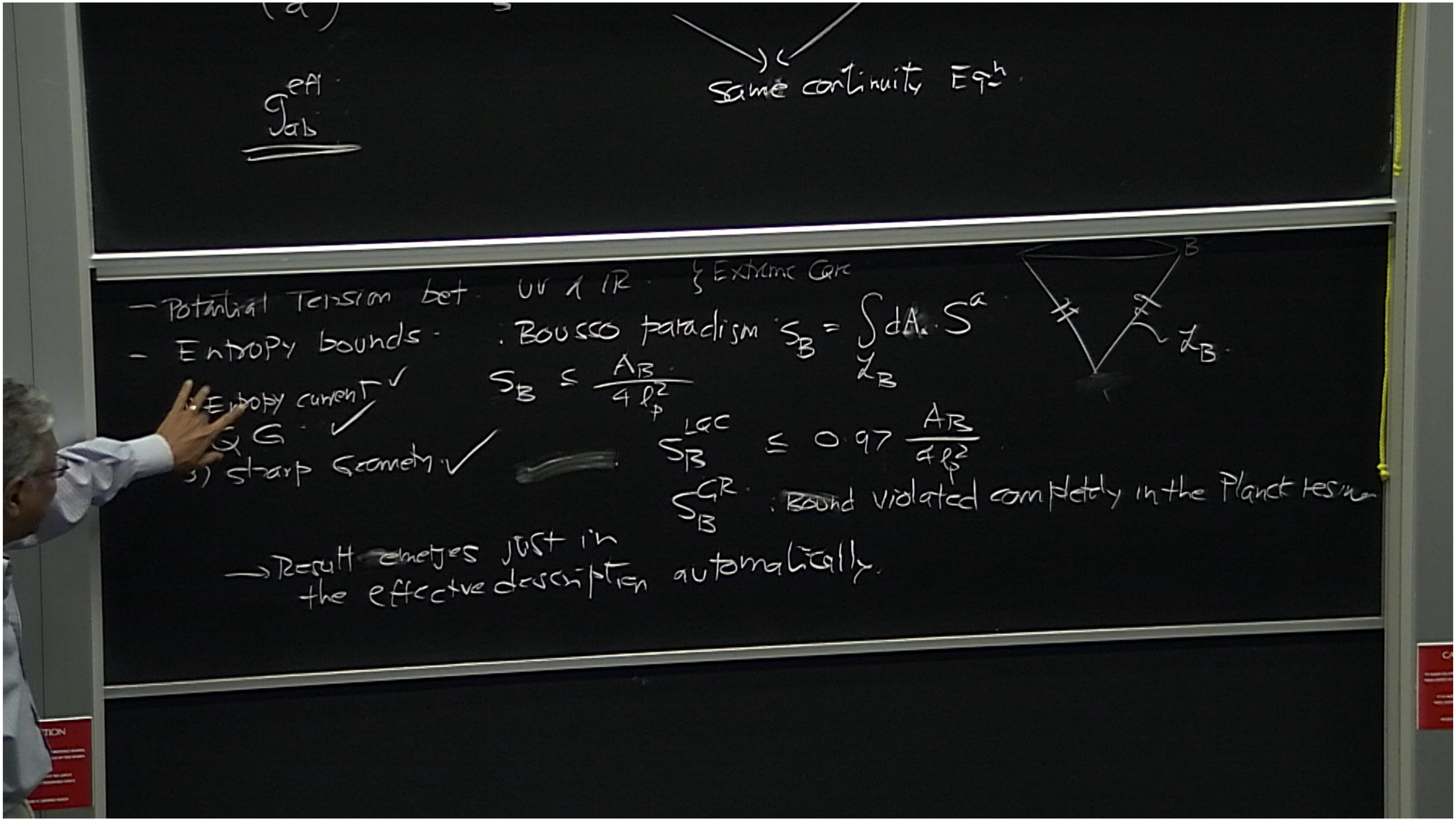
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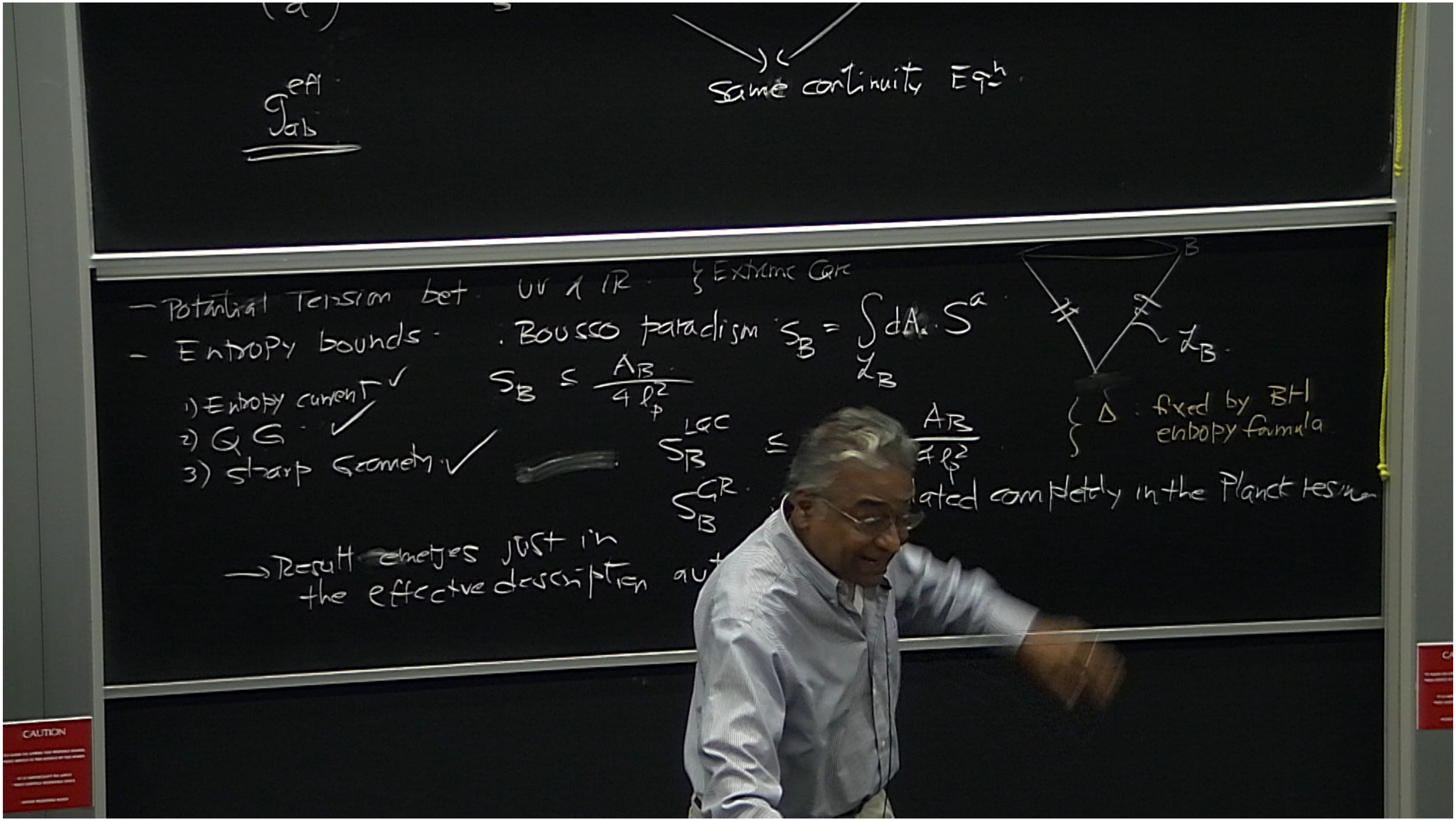
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1. QFT on FLRW $\rightarrow$ QFT on Q FLRW geometries.

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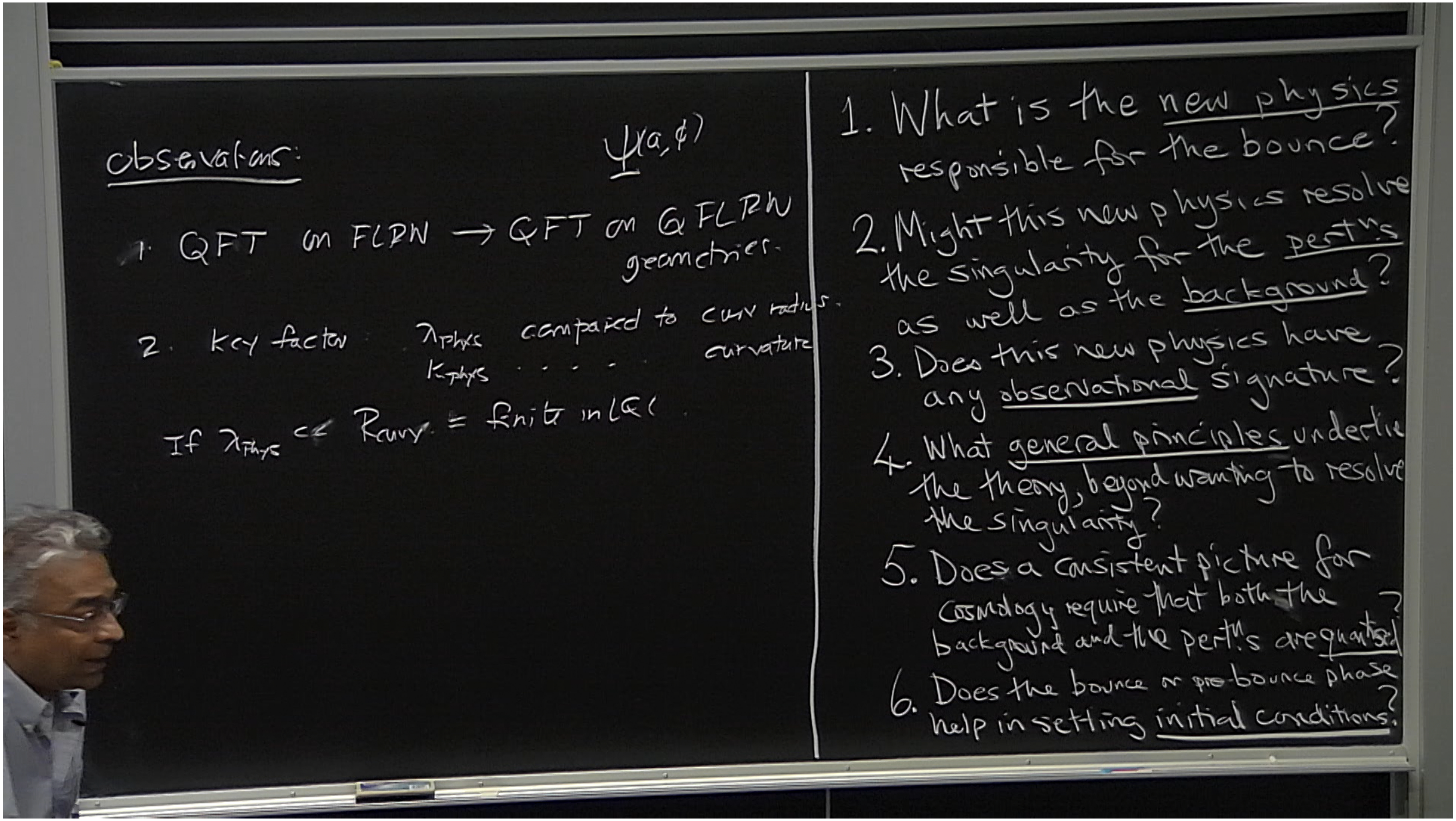
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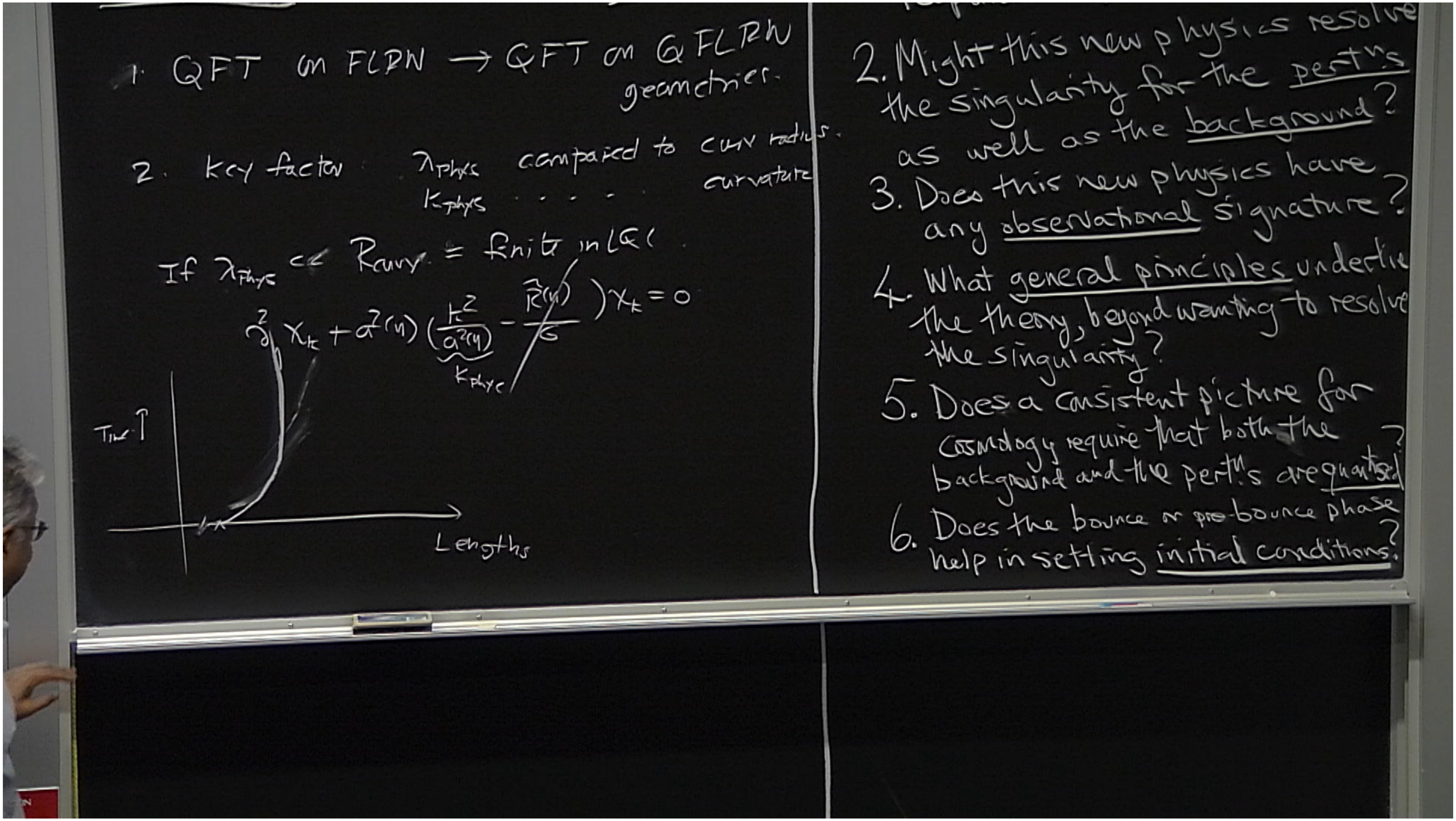
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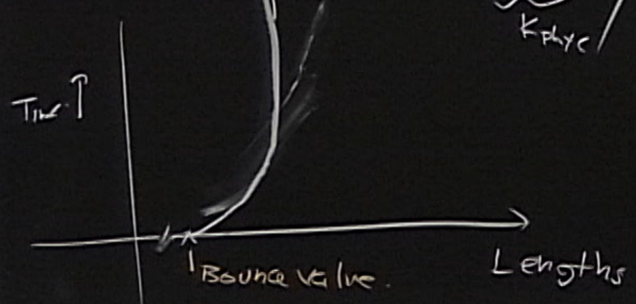

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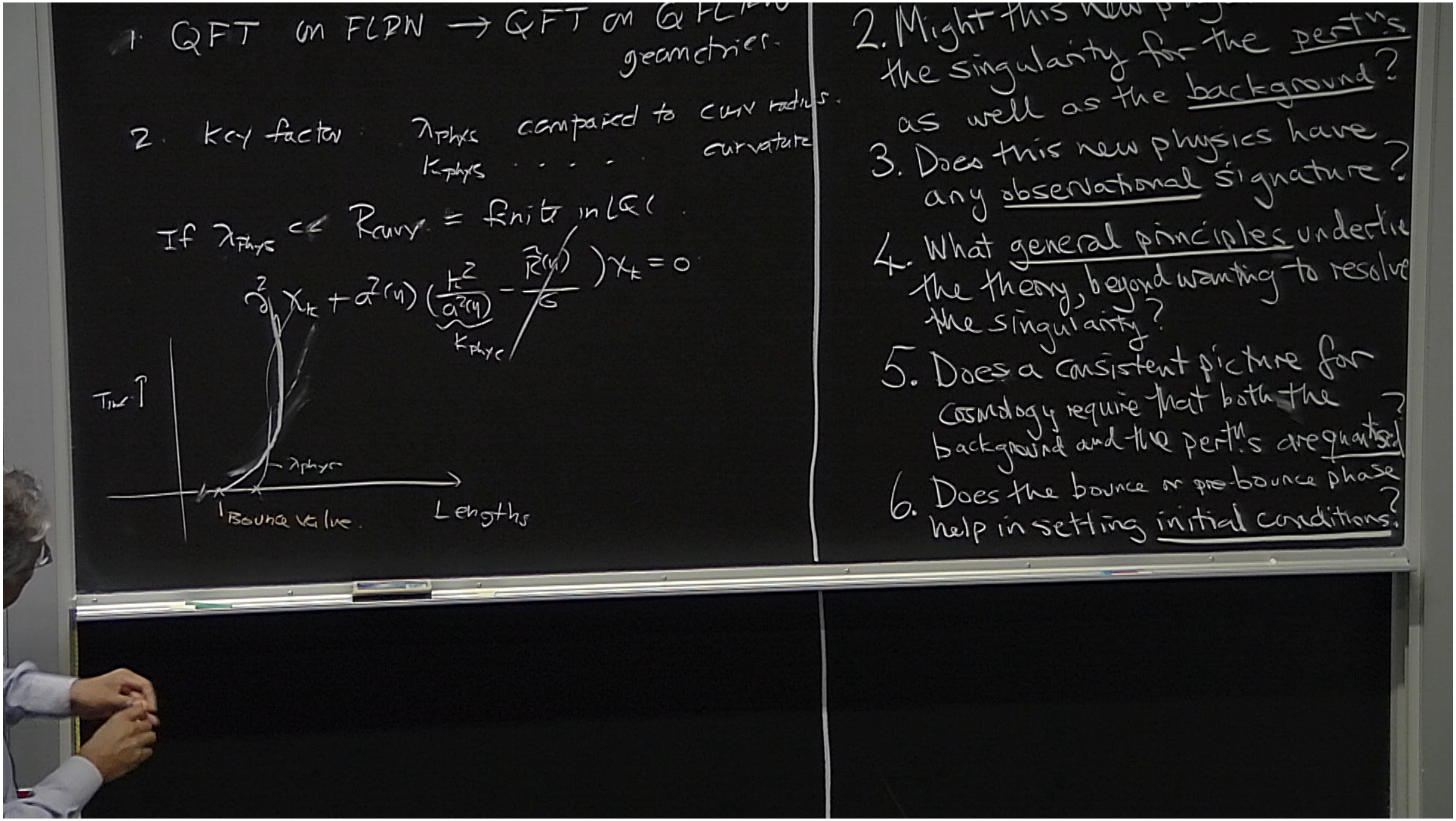
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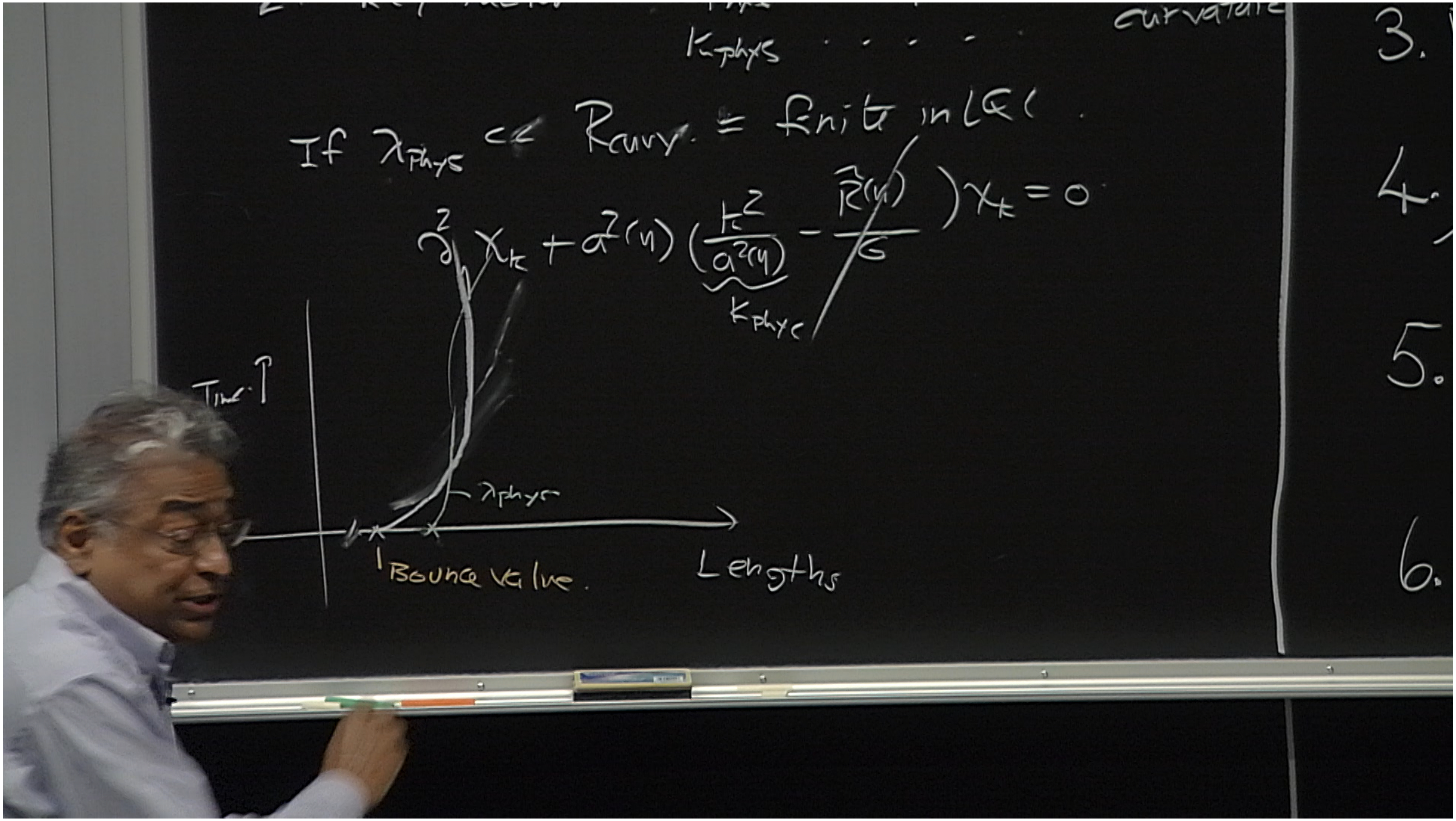
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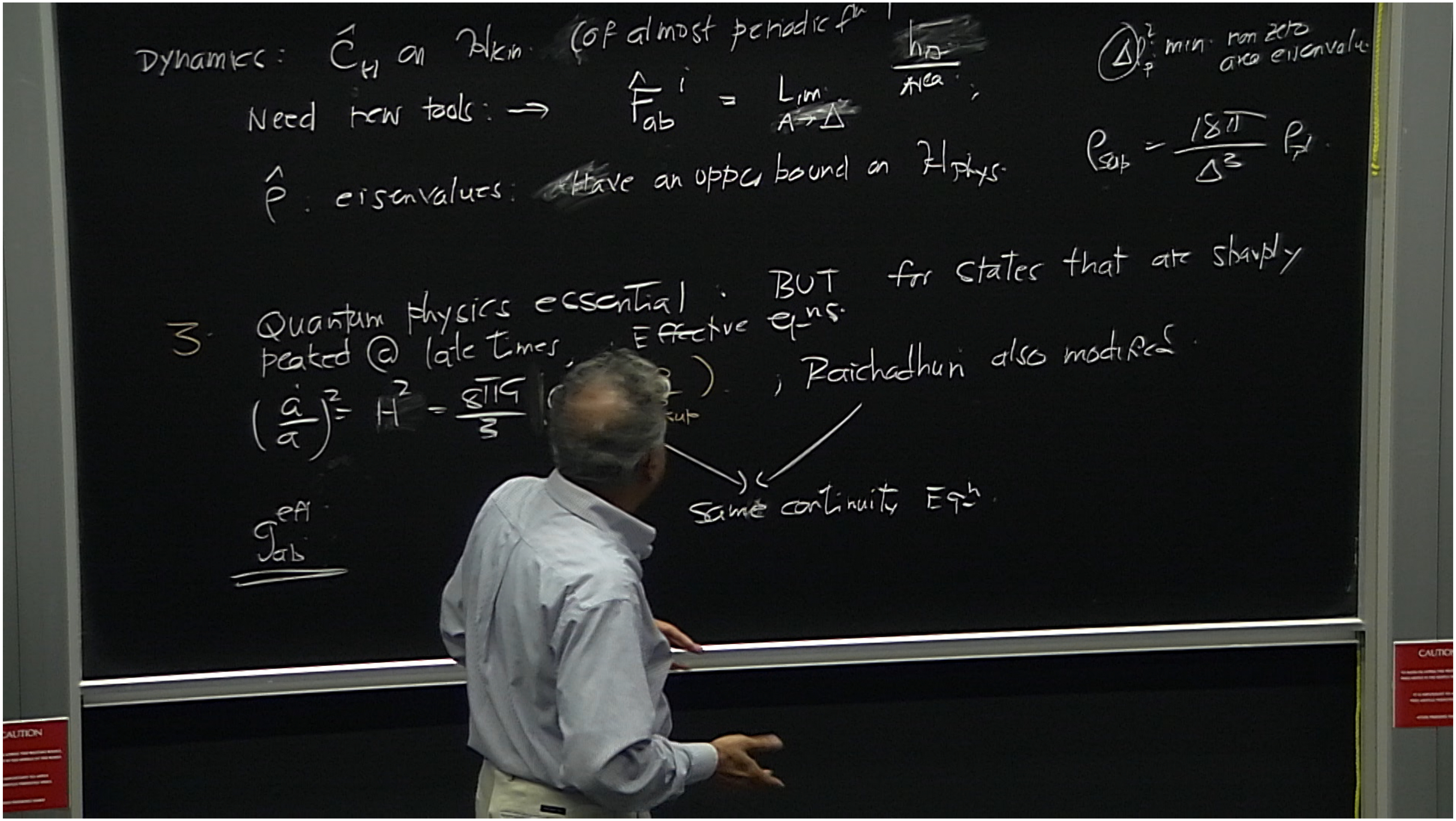
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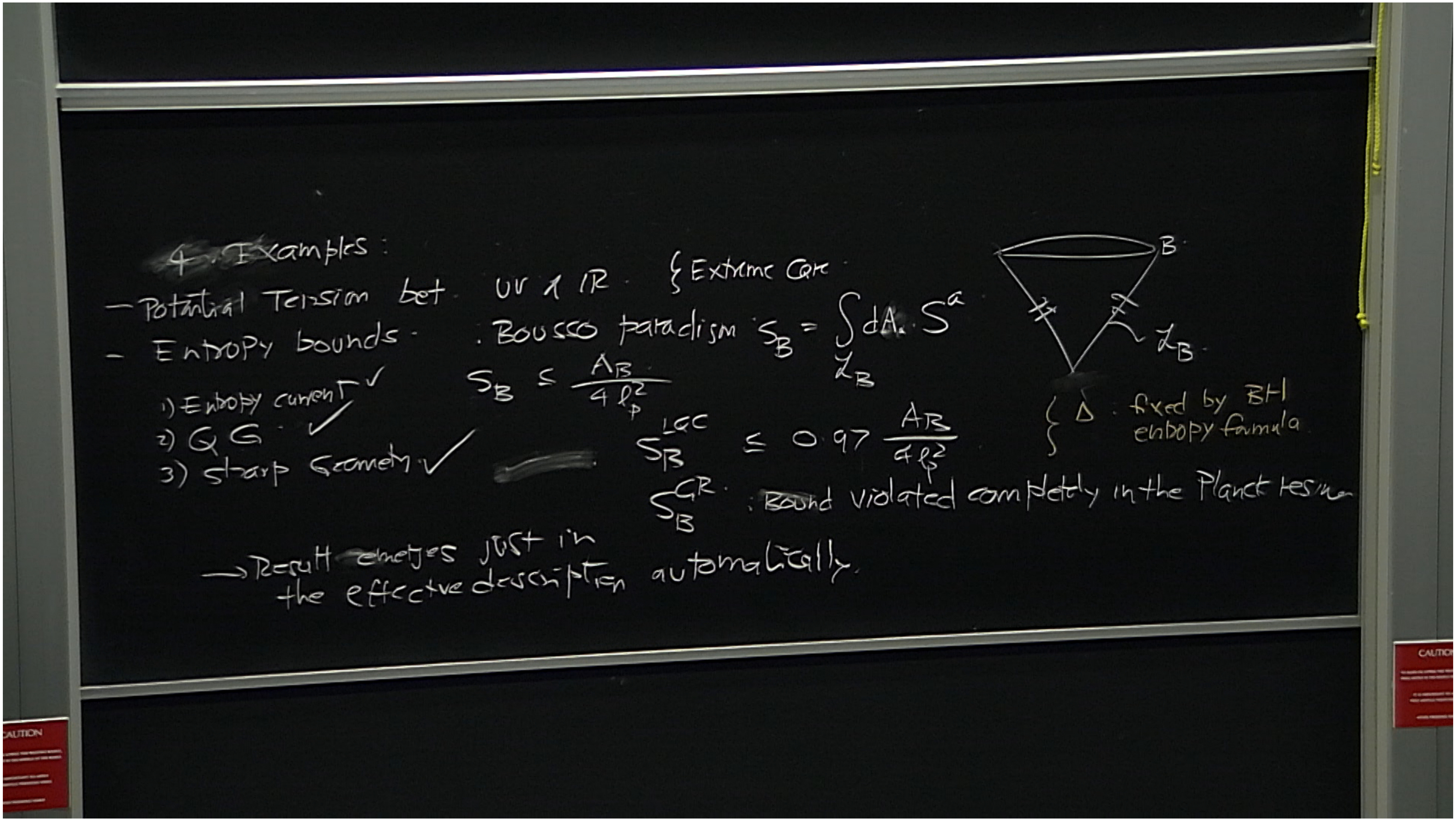
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