Title: Quantum Foundations Lecture

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Collection: Quantum Foundations

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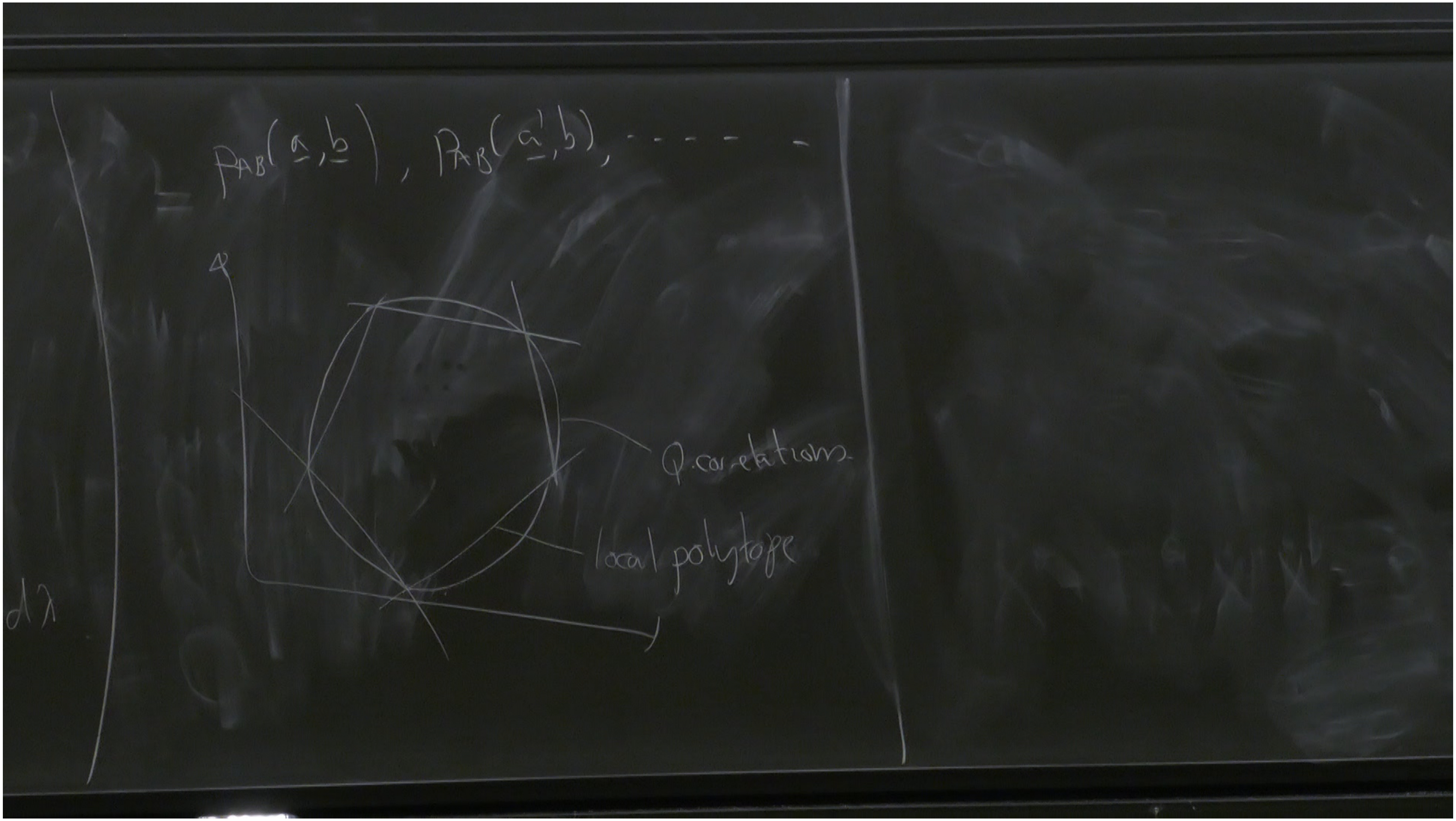
$$A(\underline{a},\lambda) = \pm 1 \quad , \quad B(\underline{b},\lambda) = \pm 1$$

Can derive Bell CHSH inequalities

with

$$p_A(\pm 1 \,|\, \underline{a},\lambda) \quad , \quad p_B(\pm 1 \,|\, \underline{b},\lambda)$$

$$p_{AB}(\pm 1, \pm 1 \,|\, \underline{a}, \underline{b}) = \int_\Gamma p_A(\pm 1 \,|\, \underline{a},\lambda)\, p_B(\pm 1 \,|\, \underline{b},\lambda)\, \rho(\lambda)\, d\lambda$$


PAB(a,b), PAB(a',b), ...
Q.correlations
local polytope
dλ

- - - -

signalling polytope

Q. correlations.

polytope

PR box.

$$E(a'b') + E(a'b) + E(ab') - E(ab)$$

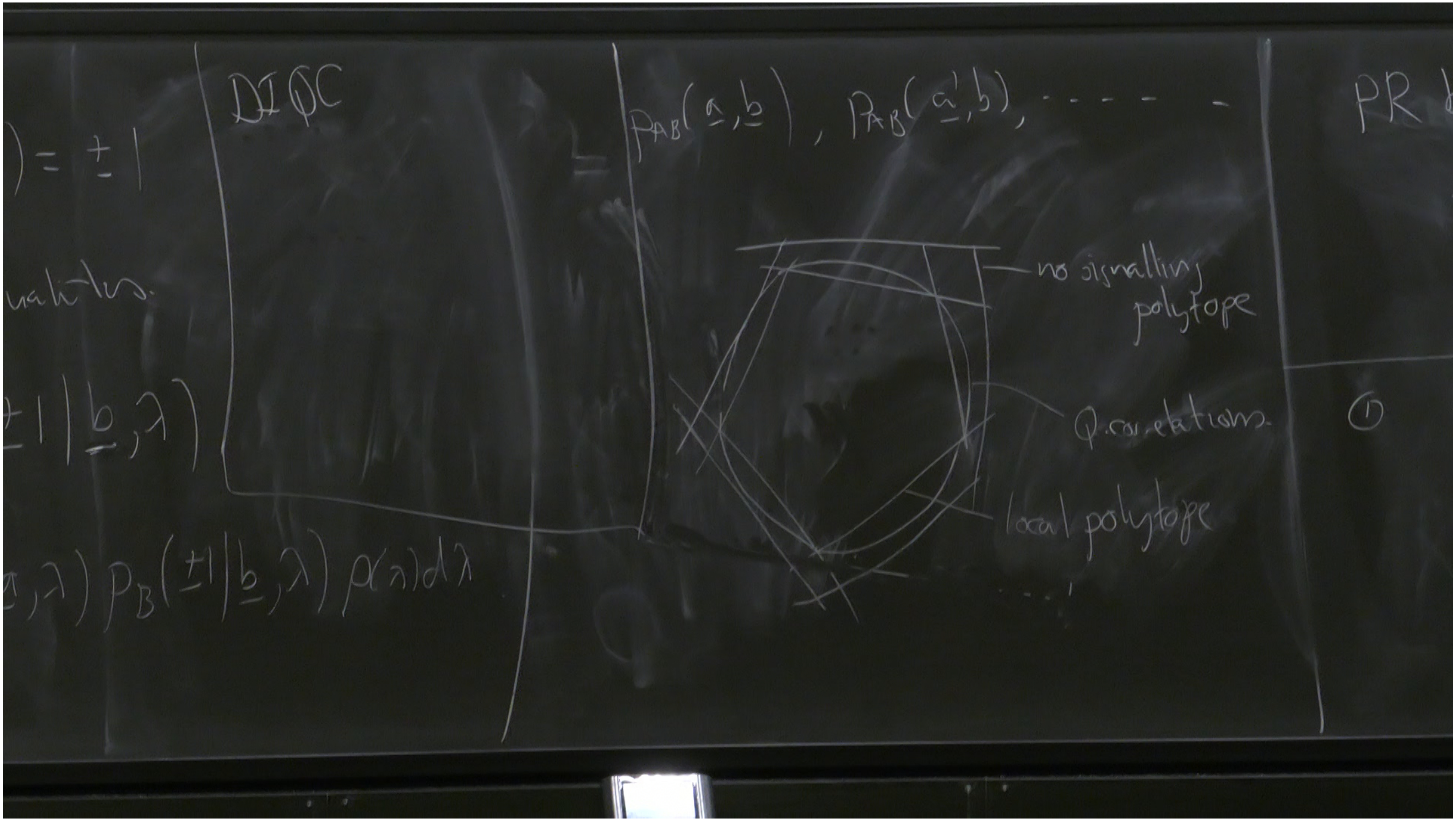
$$(+1) + (+1) + (+1) - (-1) = 4$$

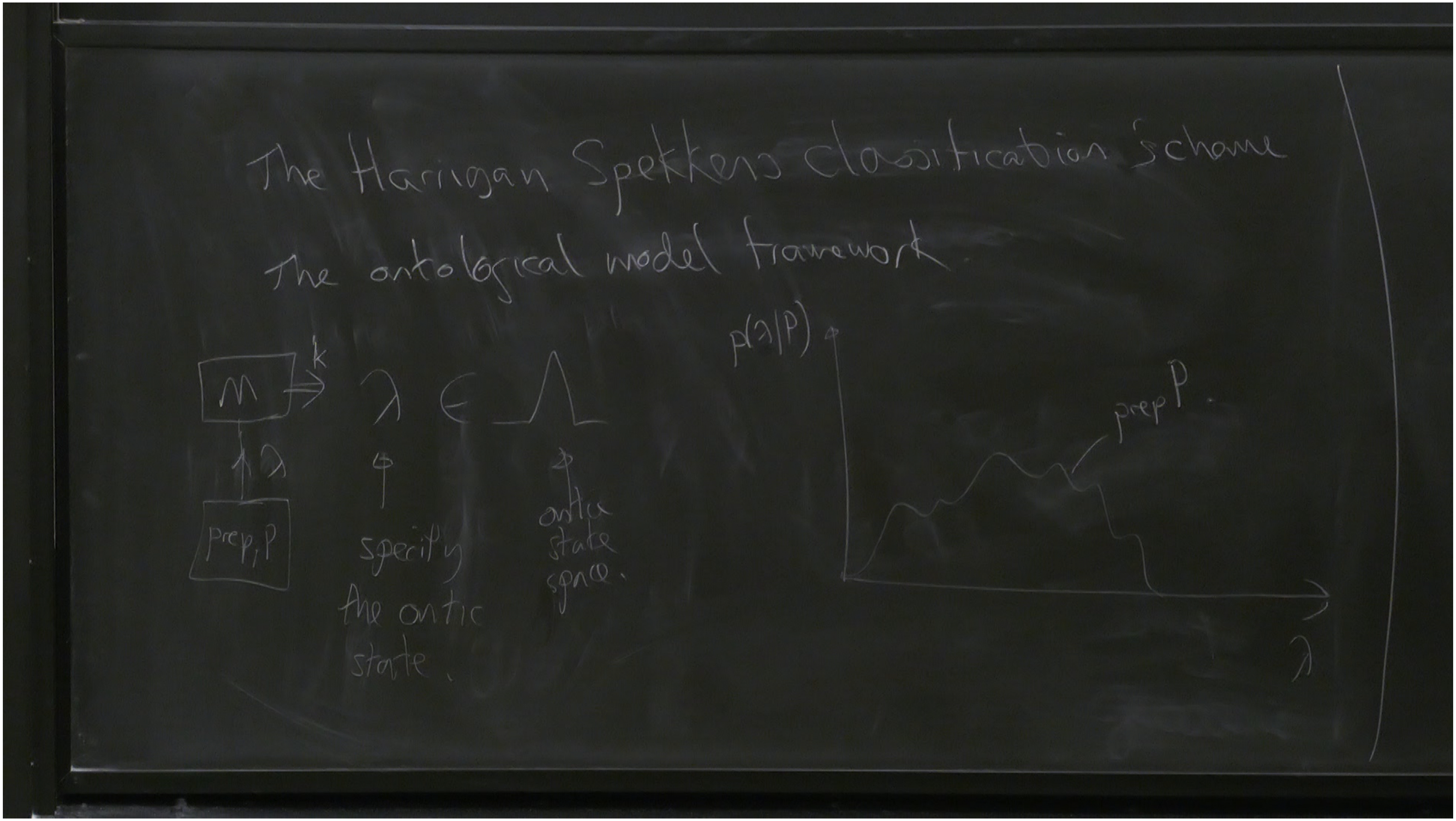
1. communication complexity.

x_A x_B

A $f(x_A, x_B)$ B

GHZ.


DIQC
$p_{AB}(\underline{a},\underline{b})$, $p_{AB}(\underline{a}',b)$, ...
no signalling polytope
Q. correlations
local polytope
PR
$) = \pm 1$
ualities.
$\pm 1 | \underline{b}, \lambda)$
$\underline{a}, \lambda)\, p_B(\pm 1 | \underline{b}, \lambda)\, \rho(\lambda)\, d\lambda$


The Harrigan Spekkens classification scheme
The ontological model framework
k
M
λ ∈ Λ
λ
prep, P
specify the ontic state.
ontic state space.
p(λ|P)
prep P.
λ

$$\text{prob}(k \mid M, P) = \int d\lambda \, p(k \mid M, \lambda) \, p(\lambda \mid P)$$

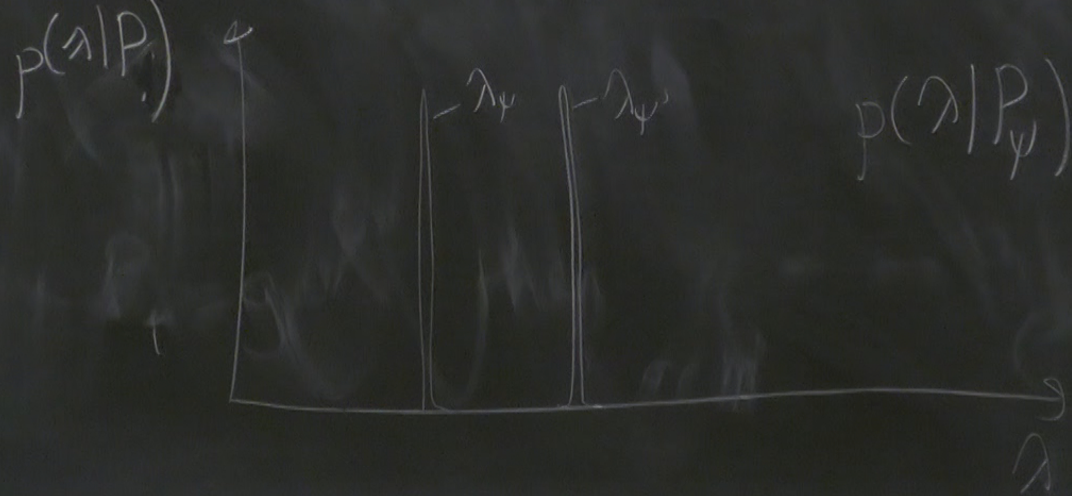
for QT

$$\int d\lambda \, p(k \mid M, \lambda) \, p(\lambda \mid P) = \text{tr}\left(\hat{E}^{M}_{k} \, \hat{\rho}_{P}\right)$$

Defn ψ-completeness.

There is a one to one map

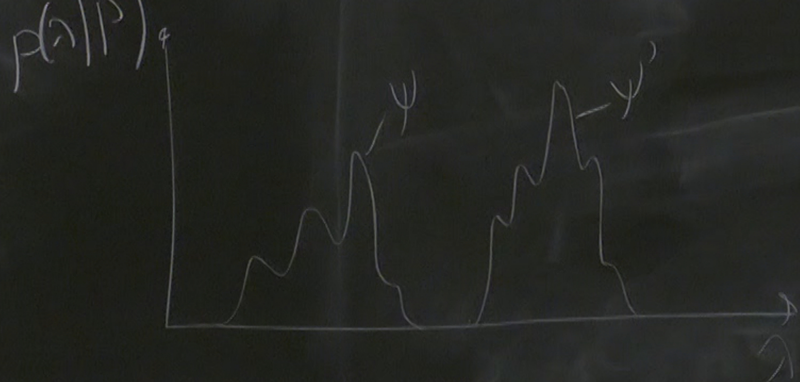
$$|\psi\rangle\langle\psi| \longleftrightarrow \lambda_\psi$$



$$p(\lambda|P_\psi) = \delta(\lambda - \lambda_\psi)$$

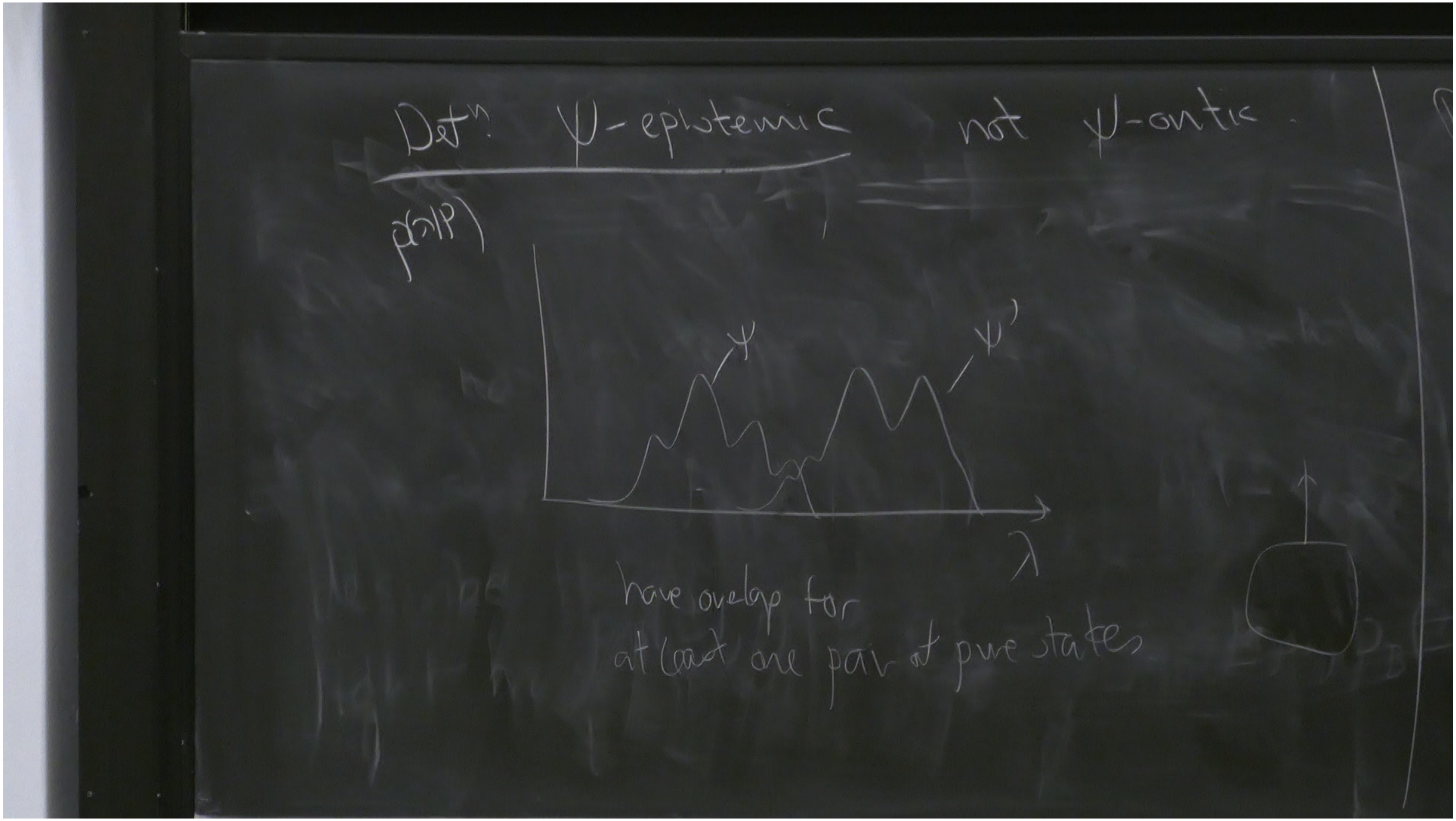
ψ-incomplete — not ψ-complete.

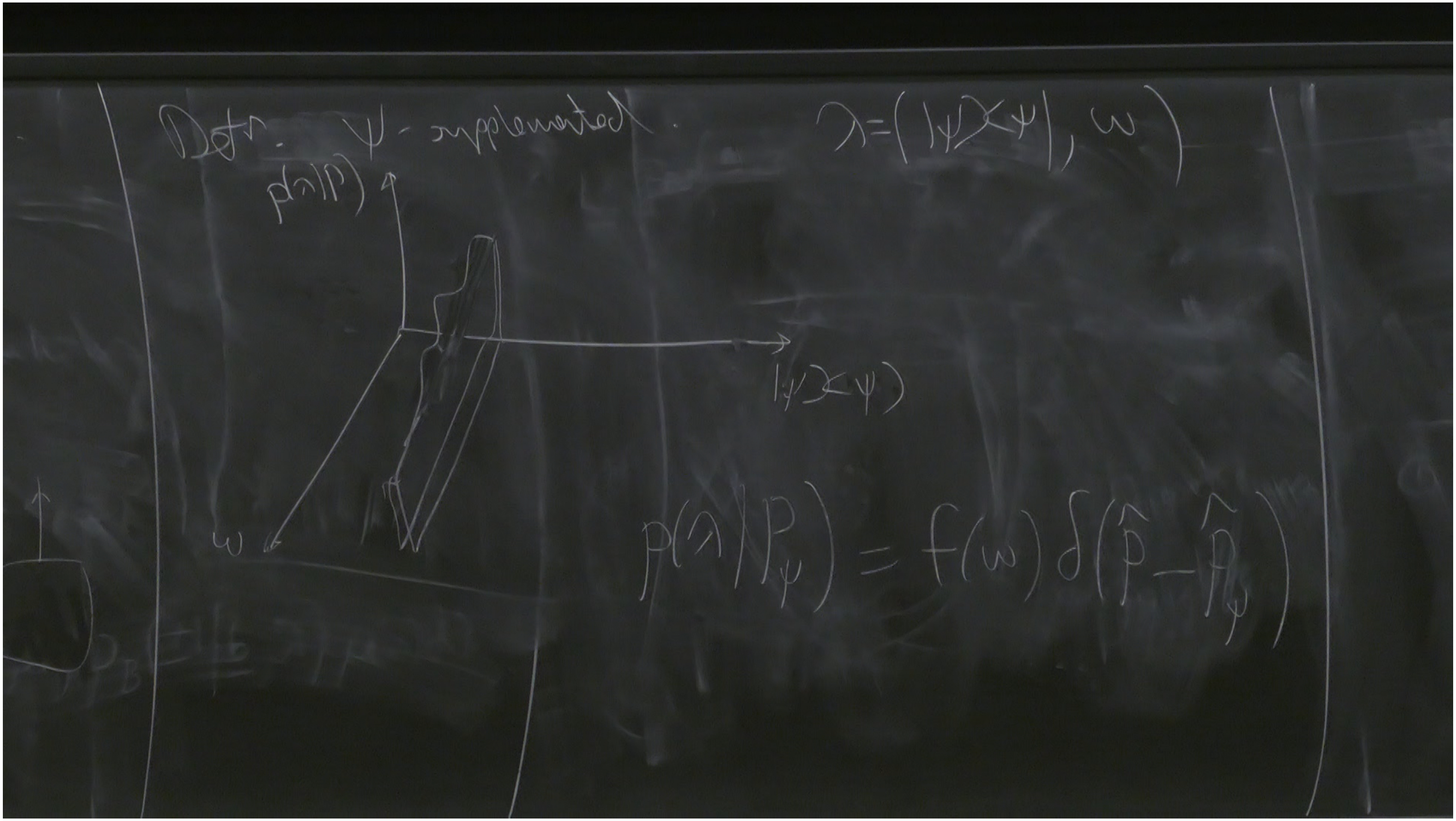
Defn: ψ-ontic. Distributions $p(\lambda|P_\psi)$, $p(\lambda|P_{\psi'})$ non overlapping for every pair of distinct pure states $|\psi\rangle\langle\psi|$, $|\psi'\rangle\langle\psi'|$.

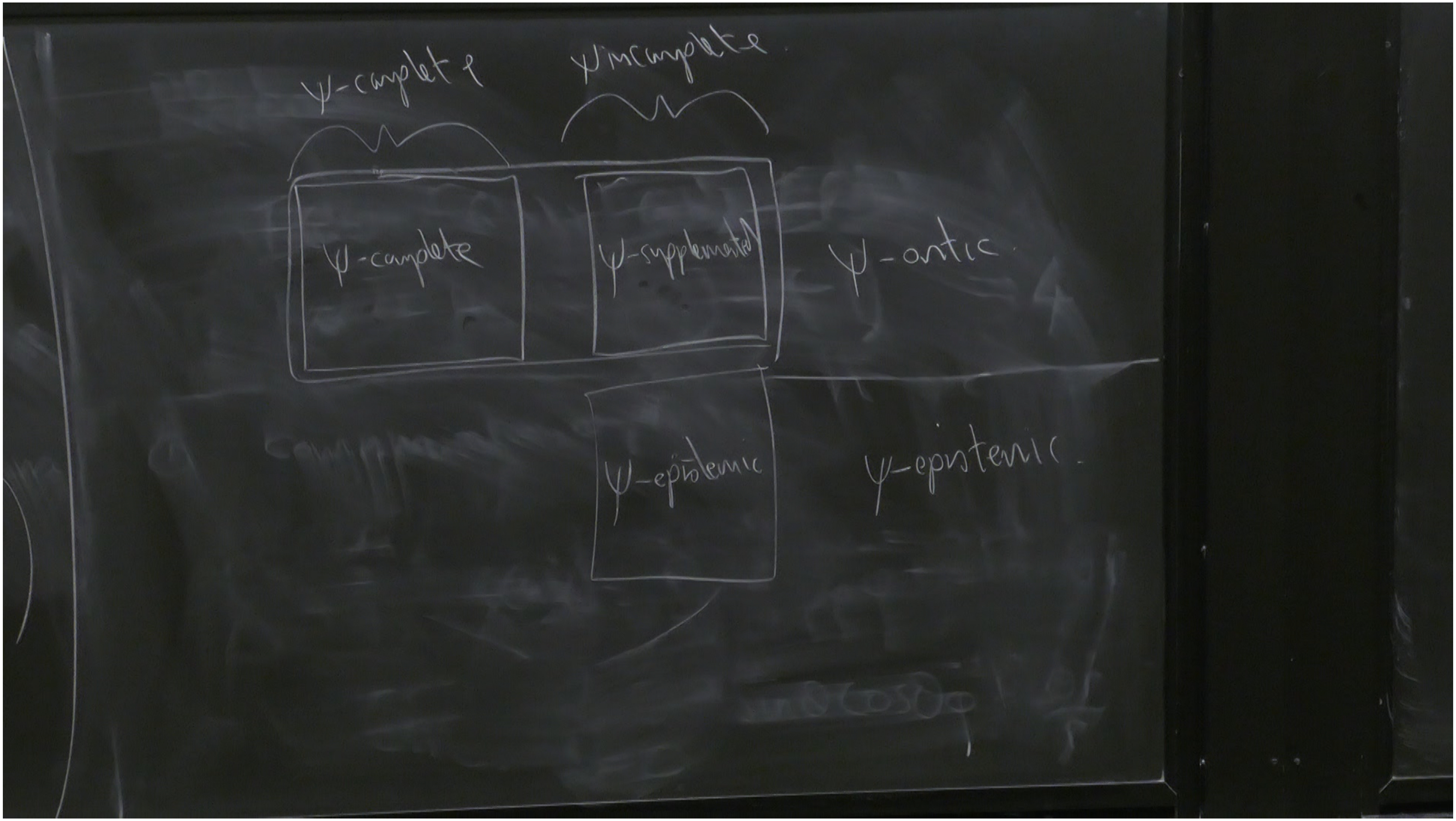


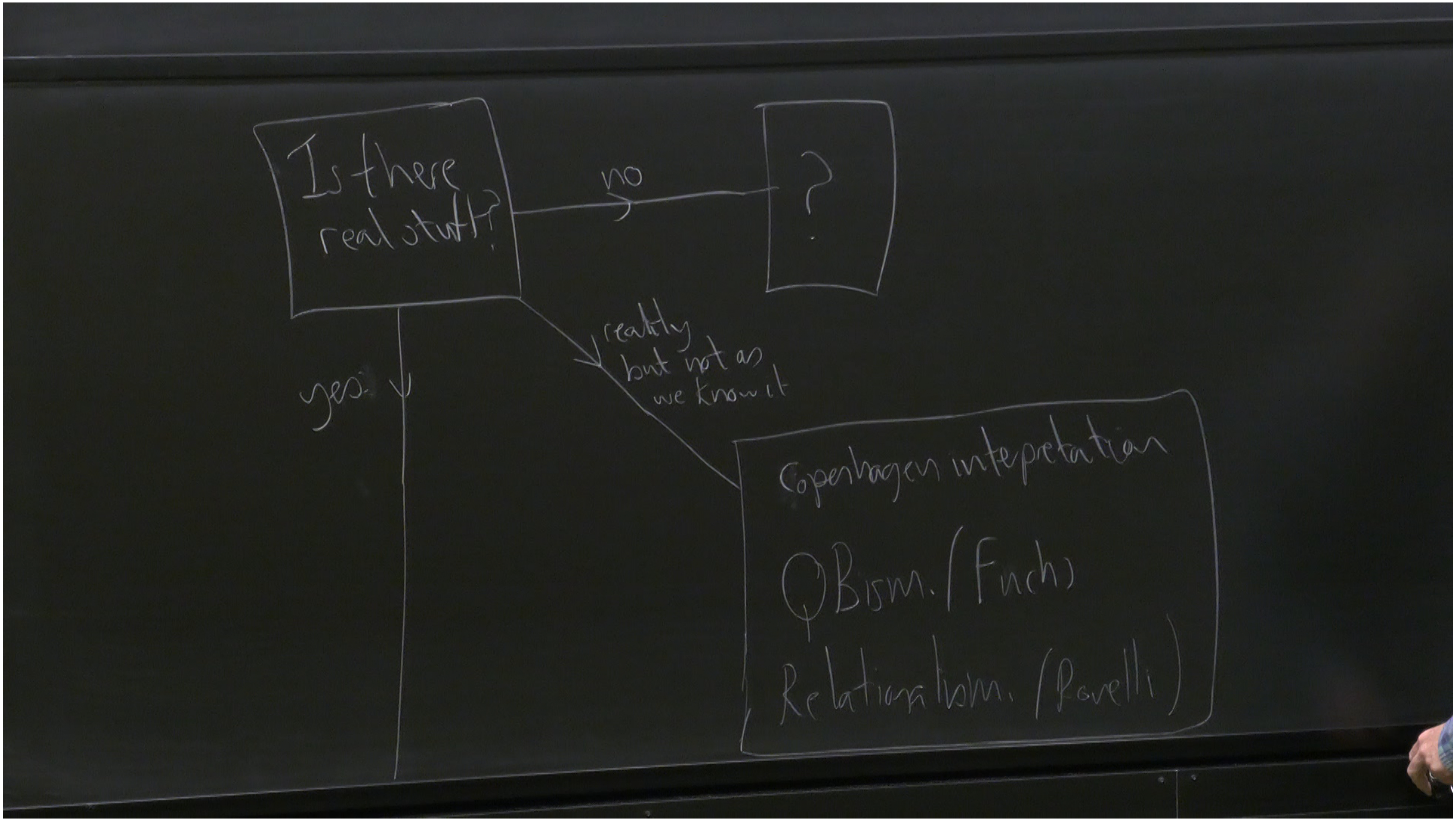
$$|\psi\rangle = a|0\rangle + b|1\rangle$$

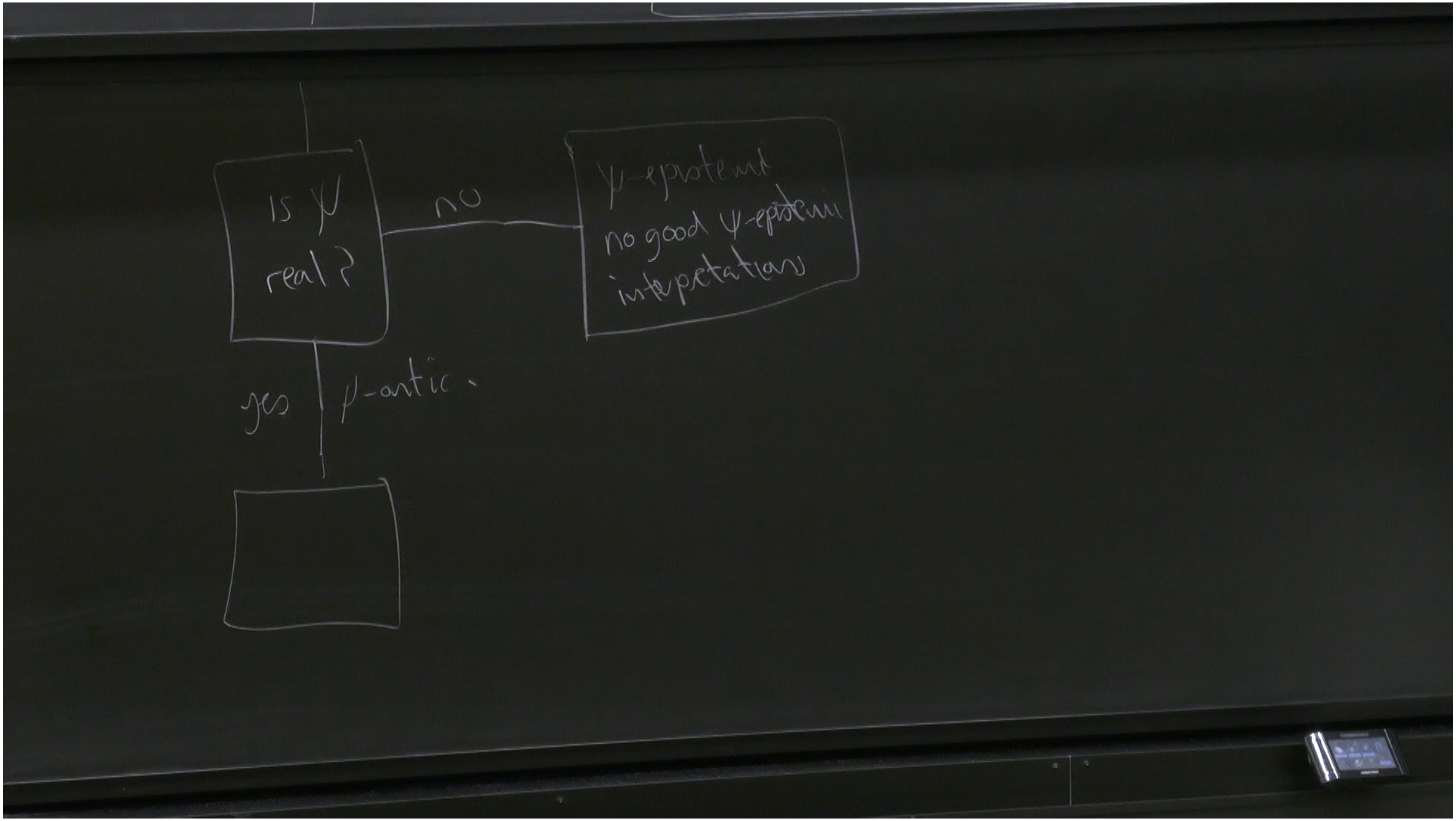
$$|\psi'\rangle = a'|0\rangle + b'|1\rangle$$

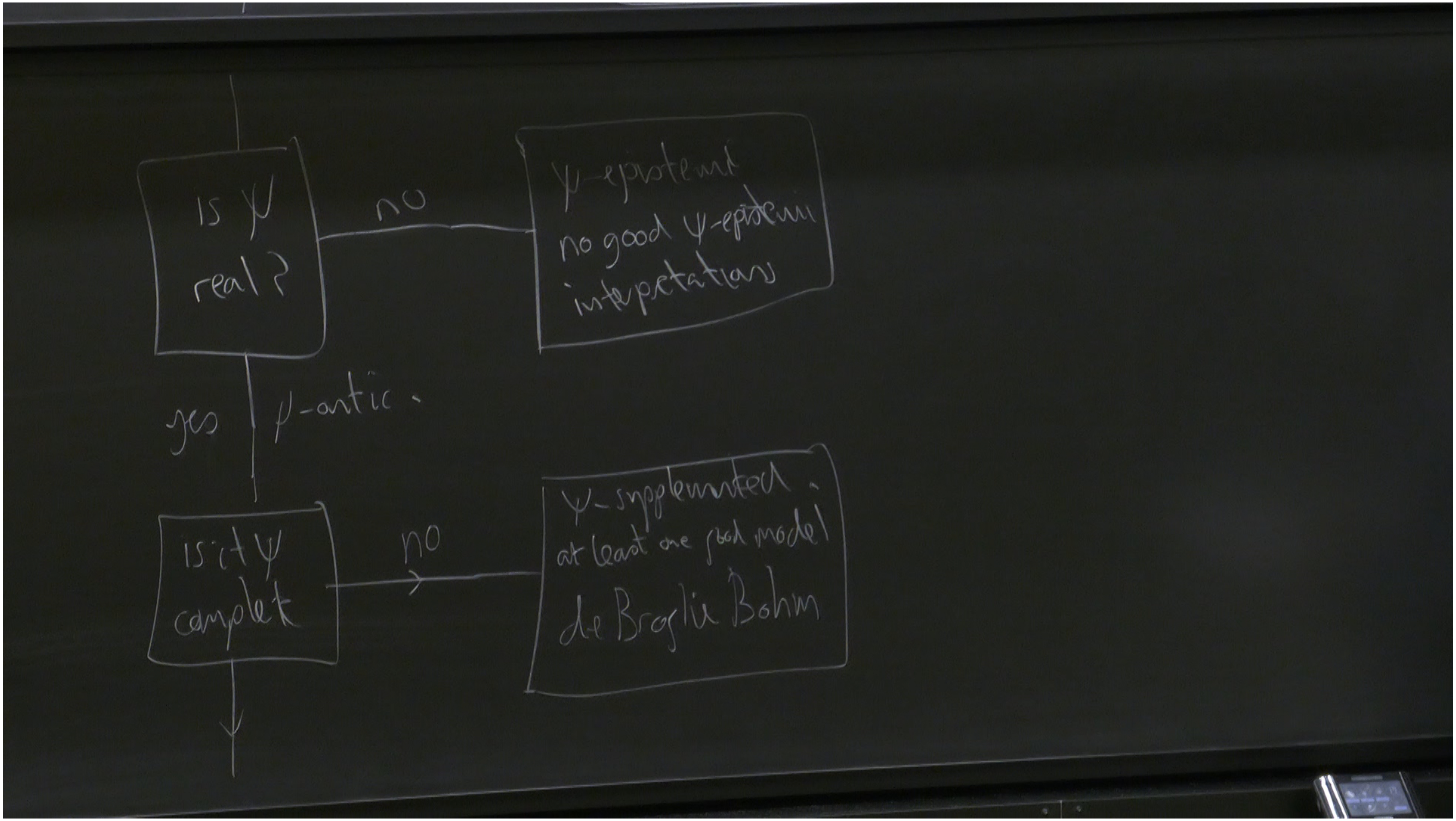

Def^n: ψ-epistemic not ψ-ontic
p(λ|ψ)
ψ
ψ'
λ
have overlap for
at least one pair of pure states


Defn. ψ-supplemented.
λ = (|ψ⟩⟨ψ|, ω)
p(λ|P)
|ψ⟩⟨ψ|
ω
p(λ|P_ψ) = f(ω) δ(P̂ − P̂_ψ)

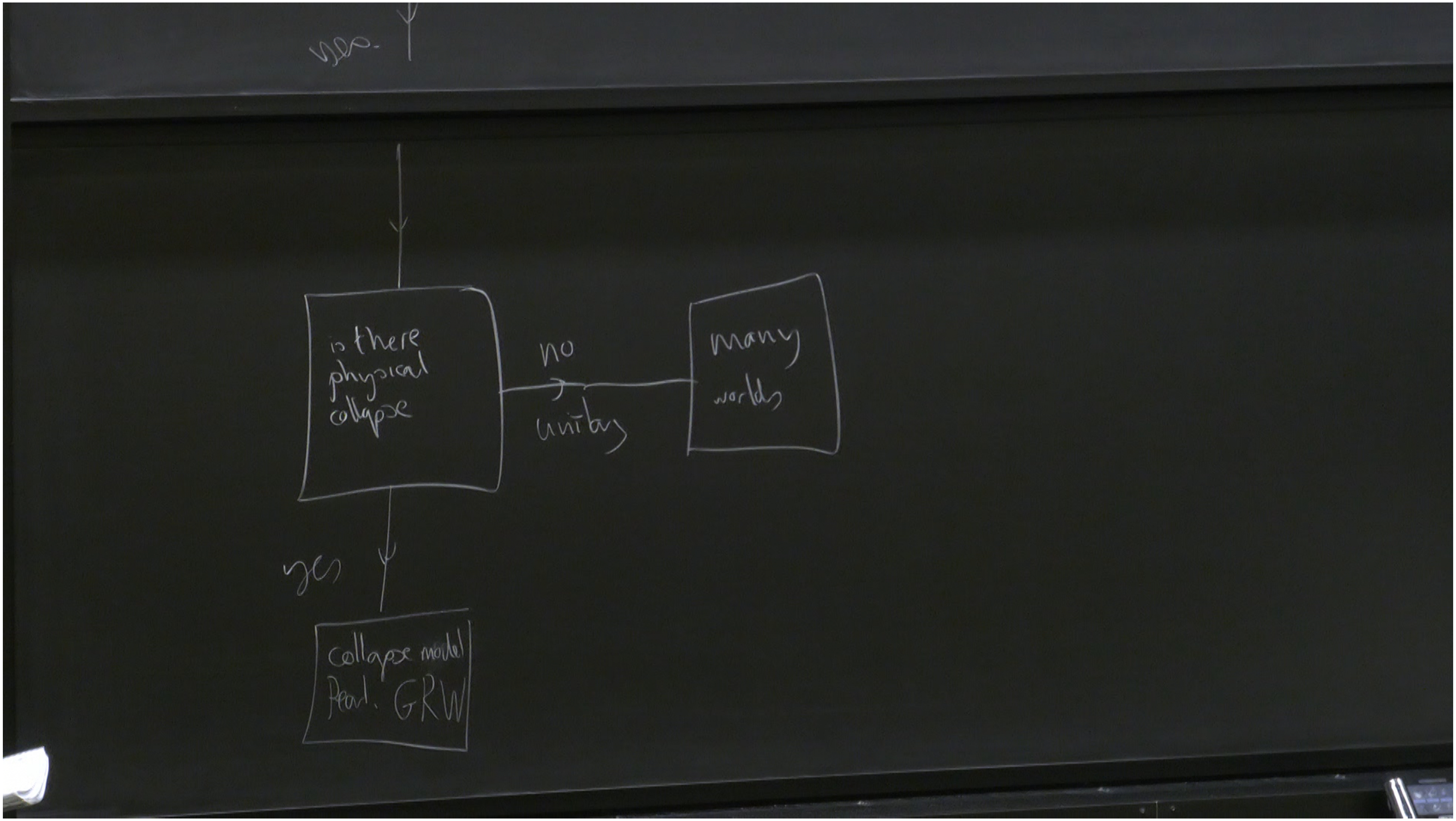

ψ-complete
ψ-incomplete
ψ-complete
ψ-supplemented
ψ-ontic
ψ-epistemic
ψ-epistemic


Is there real stuff?
no
?
reality but not as we know it
yes
Copenhagen interpretation
QBism. (Fuchs)
Relationalism. (Rovelli)


Is ψ real?
no
ψ-epistemic
no good ψ-epistemic interpretations
yes
ψ-ontic.



is ψ real?
no
ψ-epistemic
no good ψ-epistemic interpretations
yes
ψ-ontic.
is it ψ complete
no
ψ-supplemented.
at least one good model
de Broglie Bohm



is there physical collapse
no
unitary
many worlds
yes
collapse model
Pearl. GRW